SRS Needs Assessment: Phase I
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I. Executive Summary

This project was undertaken in response to the DOE's request for investigation of former workers of the Savannah River Site (SRS) who were at significant risk for health problems due to hazardous exposures during their DOE employment. Five major objectives were identified: (1) to determine if workers were exposed to harmful agents; (2) to determine health effects workers might experience due to their occupational exposures; (3) to determine which and how many workers were exposed to harmful agents; (4) to assess the feasibility of contacting former workers about their previous exposures; and (5) to identify approaches for conducting the project in partnership with relevant and interested groups. Most of these objectives were completely met, and at least portions were accomplished on all.

We found that there is evidence that workers were exposed to harmful agents while employed at the SRS. There are a variety of sources and types of chemical and physical hazards (e.g. radiation, noise, heat) found at SRS. While an extensive array of databases exist, the industrial hygiene data were not very useful in determining if workers were exposed to harmful agents because most sampling occurred from the mid-1980s onward. Previous years of operation, which probably had greater likelihood for employee exposures to hazards, could not be assessed using these records. The number of personal industrial samples was quite small in relation to the number of employees possibly exposed. Therefore, the representativeness of the available data is suspect. Also, the records reviewed were limited as to the type of hazard assessed. The records reviewed were predominantly for sampling conducted for asbestos, nitric acid, and coal dust. However, the medical records did show evidence that workers did suffer ill-effects from occupational exposures at SRS. Hearing loss (8,221) and contact dermatitis (6,005) was recorded for a large number of workers. Asbestosis and respiratory disease due to chemical exposure were also recorded; albeit to a much lesser degree. These conditions also indicate undue ill-health effects resulted from occupational exposures. We would expect to find more cases of occupationally related disease in former workers with more intensive medical surveillance activities.

We were unable to make an independent determination about which hazards employees were most likely to be exposed during their employment at SRS, because of the uncertainty and gaps in the monitoring data. Therefore, in determining the hazards and health effects to consider for medical surveillance, we relied heavily on the professional judgement of the health, safety, and medical personnel at SRS to identify health risks. From the medical records, our list of hazards and health outcomes of concern are listed in the table below:

Table 1s

Hazardous Substances of Concern and Known Chronic Health Effects

Asbestos	Mesothelioma, bronchiogenic carcinoma, asbestosis, restrictive pulmonary function, fine rales, finger clubbing, dyspnea, dry cough, and cyanosis
Beryllium*	Berylliosis, IARC classifies as a human carcinogen (lung)
Dioxane	Liver and kidney damage; animal carcinogen
Hydrazine	Liver and kidney damage; animal carcinogen
Hydrogen Sulfide	Cardiac muscle tissue damage, possibly increases heart attack risks, fatigue, headache, dizziness, and irritability
Ionizing Radiation	Most cancers
Internal Radiation	
Americium	Liver, bone cancer
Plutonium	Lung, liver, bone cancer
Tritium**	Most cancers
Noise	Hearing loss, possibly increases blood pressure
Perchloroethylene	Peripheral neuropathy, liver damage, cancer in animals, impaired memory, potential human carcinogen (NIOSH)
Polychlorinated Biphenyls	Chloracne, liver damage and cancer are also suspected effects
Transuranium	Lung, liver, bone cancer, kidney disease
Trichloroethylene***	Possible central nervous system changes, liver and kidney damage, hematological effects (including leukemia)

* While we found there is no documented exposures to beryllium at SRS, beryllium was identified as being on site in DPSOP158. Because of the DOE's interest in beryllium, we have included it in our list.

** It is uncertain if bioassays for tritium were conducted; its inclusion on this may change if future information indicates change is warranted.

*** Trichloroethylene was used in the early years of production

It should be noted that other known toxic chemicals were present (see Table 2 and Section VIIB) but we as yet do not evidence of worker exposures.

SRS medical records indicate there were 25,580 former workers at the facility. The identities of workers exposed and the number of workers exposed to harmful agents could only be approximated from available SRS data. On some employee medical records, there is a field to indicate exposure to one of several hazardous agents (E codes). Also, some employees were entered into a medical surveillance file (Tickler File) if they were known to have exposure to one of several hazards of interest. However, these files are not complete in regard to including all workers eligible for inclusion in the data files. Therefore, we had to approximate the number of workers exposed to specific hazards. As an upper bound, we calculated the potential number of people at risk for exposure by using the proportion of workers that worked in a particular production area (see Section VII, Part C, Population at Risk) and multiplied it by the total number of terminated SRS workers. A lower bound will be estimated by using the number of workers listed in the medical records (by E-codes and Tickler Files) as being exposed to a particular hazard. Although these estimates are based on assumptions that have not been tested, we do think these bounds provide reasonable guidelines regarding the worker population at risk.

Table 2s
Estimated Number of Former Workers Potentially at Risk from Exposure to Hazards of Concern

Hazard	Lower Bound*	Upper Bound**
Asbestos	1,770	4,000
Beryllium	0	100
Dioxane	8	822
Hydrazine	114	3,054
Hydrogen Sulfide	1,976	4,000
Ionizing Radiation (external)	340	574
Internal Radiation	150	---
Noise	8,221	10,000
Perchloroethylene	90	4,323
Polychlorinated Biphenyls	13	---
Trichloroethylene	---	822

See Table 12 in the Text for details.

* Based on E-codes from SRS medical records, tickler files and medical ICD Codes..

** Professional judgment of researchers and calculated number of workers in particular areas with known potential exposures.

In two separate trials to contact former workers, we found that approximately 30% could be reached by use of available information from SRS. The contact rate for retirees was higher (61%) than for employees terminated for other reasons (24%). These contact rates were based on listed addresses with no attempt being made to search for individuals. We consider it likely to be able to reach a large portion of former employees using standard search methods.

Time constraints limited our identifying key individuals and groups who would be interested in forming partnerships with our researchers in this project. However, we did obtain information on several groups of retired SRS workers and believe these groups will be willing to assist us in future projects. We intend to pursue this activity further and will update this portion of the report as needed.

During this study it was interesting to find that the most convincing evidence of work related hazardous exposure was found in medical records. Ordinarily, in an industrial setting, health physics and industrial hygiene monitoring would be used to institute controls that would prevent or reduce any loss of health from exposure to work site hazards. At the SRS, the industrial hygiene records, which could connect exposure to individual workers, were so limited that it was necessary to probe the medical records using ICD (classification of disease diagnostic codes) codes and ACR (American College of Radiology, radiographic diagnosis) codes to show the prevalence of specific diagnoses that are likely to be associated with work related, hazard exposure. There was evidence of illness related to asbestos and noise exposure in addition to a number of skin problems.

Because specific exposure information was so limited, it was not possible to reliably estimate the burden of work related ill health in the former SRS worker population. To obtain a more accurate and specific picture of the amount and type of occupational health problems in the former worker population, it will be necessary to directly study the current health status of a sizeable part of the group. From our experience with contacting small subsets of the population, a large percentage of former workers can be contacted and studied. The health of this group can be measured in a cost effective way and once the burden of ill health is determined quantitatively, some mitigation of future illness can be achieved.

II. INTRODUCTION

A. Overview of the Former Workers Health Project

Section 3162 of the National Defense Authorization Act of 1993 (Pub. L. 102-484) directed the Secretary of Energy to develop a program of medical evaluation for current and former DOE workers at significant risk for health problems due to exposures to hazardous or radioactive substances during their employment at DOE facilities. As a result of this Act, this project was developed and implemented in response to a Department of Energy (DOE) request for applications (62 FR 14122) for a two-phase project focused on medical screening of former DOE workers. The goals of this project are to identify groups of workers at significant risk for occupational diseases; notify members of these risk groups; and to offer these workers medical screening that can lead to medical interventions. Phase I of this project involves the conducting of a comprehensive needs assessment. Phase II, if the Phase I needs assessment warrants it, would involve contacting former workers at risk for adverse health effects and providing medical advice and services to those concerned of about past exposures affecting their health. The current project is in Phase I, the needs assessment, and will be the focus of the remainder of this report.

As directed by the DOE, the Phase I needs assessment is to identify existing information relevant to exposure and health outcomes among former workers; identify or develop means to contact these workers; provide an initial determination as to the most significant worker hazards, problems, or concerns at a site; develop approaches for conducting the project in partnership with unions, site management, operating contractors, community representatives, and State and local health officials. This report discusses our approaches, the data sources used and findings obtained from these sources in regard to identifying exposures of concern, health effects related to such concerns, as well as former workers at risk for hazardous exposure. An estimate of the number of workers potentially at risk for exposure is also provided. Further, a determination as to the need for future medical surveillance is provided along with potential health outcomes that may be examined during medical surveillance activities. The report begins with a detailed description of the SRS, so that a basic understanding of the processes and potential hazards is established.

B. Description of Savannah River Site

In 1950 the Du Pont Company contracted with the Atomic Energy Commission for a fee of one dollar to design, construct, and operate an atomic plant to produce materials (primarily plutonium and tritium) for use in building nuclear weapons. The Savannah River Site (SRS) was chosen as the location for this plant. It is located on a 300-square-mile tract of land in South Carolina on the Savannah River below Augusta, Georgia. Du Pont managed the site until 1989, after which Westinghouse Savannah River Company took over its management.

The SRS consists of groups of buildings, or areas, with similar purposes that are designated as Heavy Water Processing, Fuel and Target Fabrication, Reactors, Separations, Administration, and Waste Management. Each area will be discussed separately, although they are by necessity interconnected.

Heavy Water (400) Area

The Heavy Water Processing Area (or 400-area or D-area) serves the purpose of manufacturing heavy water, or deuterium (D2O). Production began in 1952 and ended in 1981 when it was decided that there was a sufficient supply of deuterium. Heavy water was used to remove heat from nuclear reactions and to moderate the reaction by slowing down neutrons. Heavy water was produced by taking natural water from the Savannah River and forcing hydrogen sulfide gas through it at high pressure in a countercurrent, first in a cold tower, then in a hot tower. "GS", or Girdler Sulfide units, were used for this initial step, which concentrates D2O to approximately 15%. This water was then put through a distillation process, which separated the light and heavy water through a fractional, vacuum distillation, to a concentration of greater than 90%. The third and final step was an electrolysis process, which concentrated the heavy water to about 99.8% purity using potassium carbonate. The last step was discontinued in 1958 since at that time they were able to achieve sufficient purity through the distillation step. The hydrogen sulfide required for production was manufactured in the 400 D-area until the late 1960's, when it began to be brought from off-site. The heavy water plants in buildings 411-D and 413-D were shut down in 1957 and 1958. The last heavy water production unit in building 412-D was shut down in 1982 (Bebbington, 1990).

Other buildings in the Heavy Water Processing area include the Heavy Water Rework Facility, where heavy water that had become mixed with light water or tritium in the reactors was repurified through distillation and ion exchange. Another facility in this area is the Defense Waste Processing Facility, which was built to process radioactive wastes into borosilicate glass with reduced radioactivity, which would then be sealed in stainless-steel canisters and welded shut for permanent storage. Testing began in this facility in 1990, and cold testing runs were finished in 1993 (RAC, 1995). In the Heavy Water Analysis laboratory in building 772-D heavy water production was analyzed and monitored. The laboratories in this area were shared with the Reactor Area, and reactor control analyses were also done in this area. The Purification and Drum Washing Facility treated Savannah River water, which was to be used to produce the D2O. The Flare tower disposed of routine leakage as well as emergency releases of hydrogen sulfide, after changing it to sulfur dioxide. The D-area Powerhouse, a coal-fired power plant in building 484-D, provided steam and electricity. There were also dedicated maintenance buildings for this area (RAC, 1995).

Fuel and Target (300) Area

The Fuel and Target Fabrication Area (or 300-area or M-area) produced and prepared fuel and target elements required for the reactors. Production began in 1953, and the two main fuels and target forms manufactured were of uranium and lithium-aluminum alloy, depending on whether plutonium or tritium needed to be produced in the reactor. These materials needed to be cladded in another material, such as aluminum and silicon or, later, nickel, to keep the uranium from corroding in the water, and to keep the fission products from contacting the water (RAC, 1995). A typical cladding would consist of taking a uranium cylinder, and heating it in a bath of molten bronze, then in a bath of molten tin. An aluminum can in a steel sleeve was immersed in molten aluminum and silicon. The uranium was then inserted in the aluminum can and an aluminum cap was welded to it. It was then exposed to hot water under pressure in an autoclave (Bebbington, 1990). Through the years the cladding process became more and more advanced. Thorium was also canned in 1964 and 1965 to produce uranium-233 for the Breeder Reactor Program (reactors that would produce more fuel than they consume) (Bebbington, 1990). Large amounts of chlorinated organic solvents were used to degrease the components, and they have contaminated the groundwater in this area (Bebbington, 1990; RAC, 1995).

Building 321-M was used for enriched uranium-235 fuel production as well as a variety of different alloy compositions of fuel tubes. In building 320-M lithium and aluminum tubes were extruded for tritium production. In building 322-M a metallurgical lab worked with neptunium oxide recovered in Separations to reduce it to neptunium metal. The Metallurgical Laboratory tested specimens of all materials fabricated. Analysis of incoming materials for fuel and target fabrication was performed, and quality-control analysis of purchased material was done. Building 313-M was the Canning and Storage Building, where cladding, canning, and storage of targets took place. A 305-M Test Pile Reactor operated from 1952 to 1980 as a graphite-moderated zero-power reactor to test slugs and rods for reactivity and neutron absorption efficiency, to calibrate neutron flux monitors, assay fuel and target slugs, and conduct engineering experiments (RAC, 1995).

Reactor (100) Area

In the Reactor Area (or 100-area) there were five nuclear production reactors. The R reactor ran from 1953 to 1964, C reactor from 1955 to 1985, P reactor from 1954 to 1988, L reactor from 1954 to 1968 and again from 1985 to 1988, and K reactor from 1954 to 1988 and then was restarted in 1991 and is on "cold standby" as of 1993 (RAC, 1995). The primary aim of the reactors was to produce plutonium and tritium from uranium and lithium absorption of neutrons; however, other missions were also undertaken. The Thorium Breeder Reactor Program ran from 1956 to 1971. There also was experimental production of synthetic elements such as neptunium, americium, curium, and californium. One of the reactors was operated at the highest neutron flux intensity ever attained, 175 times that of a typical power reactor (Bebbington, 1990). There was also a Heavy Water Components Test Reactor, which ran from 1961 to 1964, and it tested proposed fuel assemblies and other reactor components of potential use in heavy water-cooled and moderated power reactors. This reactor is located in the U-area, now called the B-area (RAC, 1995).

Fuel and target components were assembled, tested and inspected, and prepared for insertion in the reactors. These assemblies were then irradiated in a reactor, with heavy water acting to moderate and cool the reaction as it circulated through the fuel and target assemblies. A purification area served to purify the heavy water moderator and the helium gas blanket that circulated over the moderator to prevent explosion, carry away impurities, and prevent moderator degeneration (RAC, 1995). Secondary cooling was provided by Savannah River water. Certain neutron "poisons", such as gadolinium nitrate solution, could be used to shut down an out of control reaction. Depleted fuel and irradiated components were moved by conveyor from the reactor to a disassembly basin where they were stored under water with cooling cells to allow decay of the short-lived fission products. They were then disassembled, and the target assemblies with plutonium were sent to F-canyon in the Separations Area, while the fuel assemblies were sent to H-canyon in the Separations Area (RAC, 1995). The reactors were housed in buildings heavily shielded with concrete, and production was performed remotely. Spaces occupied routinely by people were ventilated separately, while reactor process areas had once-through ventilation that was held at lower pressures than the populated areas (Bebbington, 1990).

Separations (200) Areas

The spent fuel and target assemblies were sent to the Separations Areas (or F- and H-areas, the 200-areas, or the "Canyons"). The canyons were also heavily shielded buildings with operations and maintenance that were performed remotely. However, the cranes that were used to do the processing were repaired by direct maintenance. Some of the highest radiation exposures received were by these repairmen, although the amount reduced over the years (Bebbington, 1990). Ventilation flowed from the offices to the processing areas, and the air was treated before release. Each of the 221-F and 221-H facilities had two parallel lines of process cells (the "warm" and "hot" canyons) with a central system of corridors (RAC, 1995). Here the products produced in the reactors were recovered through chemical separation. In the "hot" canyons, the initial separation of the highly radioactive uranium, plutonium, and unwanted fission products took place. In the "warm" canyons there were second uranium and plutonium cycles in which nearly all the fission products were removed.

Beginning in 1954, the F-Canyon used a Purex solvent process to recover plutonium from reactor-irradiated uranium using the solvent tributyl phosphate in a hydrocarbon diluent (initially Ultrasene, a kerosene, and later Adakane, an n-dodecane, which is a more stable hydrocarbon). The F-canyon was shut down from 1957 to 1959 to install larger equipment. In building 221-F aluminum cladding and aluminum-silicon bonding was removed by dissolution in boiling sodium hydroxide and sodium nitrate, and then washed in water (RAC, 1995). The uranium was dissolved in hot nitric acid catalyzed with mercuric nitrate. Separated uranium was sent to A-line for further processing into uranium trioxide powder. Separated plutonium was sent to JB or FB line for conversion to plutonium metal. The 235-F Metallurgical Building fabricated reactor target components (RAC, 1995).

In 1955, the H-canyon initially used a Purex process, and then a modified process known as an HM solvent extraction process, to separate uranium, plutonium, neptunium, and fission products. In building 221-H the aluminum cladding and the uranium-aluminum alloy core of irradiated fuel assemblies were dissolved together in nitric acid with a mercury catalyst. In 1969 an electrolytic dissolver was added for cladding resistant to nitric acid, such as stainless steel and zirconium. The neptunium-237 and plutonium-238 products were sent to the HB line to be converted to oxides (RAC, 1995). The uranium and plutonium products were sent off-site, and the neptunium oxides were sent to the Metallurgical Building for refabrication into billets for reactor elements (Hickey and Cragle, 1985). Again, there were also special programs run time to time, such as processing highly irradiated plutonium rich in transplutonium nuclides, or recovering uranium-233 from irradiated thorium (Hickey and Cragle, 1985).

In both 232-F and 232-H buildings there was recovery of tritium from irradiated lithium-aluminum control-rod slugs (232-F was shut down in 1958 and replaced by 232-H-2). Tritium was formed and released in three processes: neutron irradiation of lithium, neutron irradiation of deuterium in heavy water moderators of reactors where it was released to air, and the release of fission-product tritium during reprocessing of reactor fuels where it was either lost to the atmosphere or converted to tritiated water during the dissolution of fuel cladding (Hickey and Cragle, 1985). In the separations buildings irradiated lithium-aluminum targets had the tritium separated from helium isotopes by vacuum, then from other hydrogen isotopes, and packaged for use. Building 234-H was used to produce reservoirs filled with tritium at high pressure. Building 238-H refilled and reused those reservoirs. In 1994 a Replacement Tritium Facility was designed to unload, mix, recycle and reload tritium, which replaced most of the other SRS tritium processing facilities (Hickey and Cragle, 1985).

There were a number of other activities included in the F- and H-areas. From 1973-1983 a Plutonium Fuel Form Facility (PuFF) manufactured encapsulated plutonium-238 oxide fuel forms, and from 1978-1982 a Plutonium Experimental Facility (PEF) provided semiworks capability and technical support for developing the processes that were developed at PuFF. A Multipurpose Processing Facility began in 1978 to process transplutonium elements. A Naval Fuel Manufacturing Facility (FMF) operated from 1981-1989 in building 247-F to manufacture highly enriched uranium fuel (RAC, 1995).

Various activities took place in the 211-H and 211-F buildings. A Bulk Chemical Storage Facility received and stored bulk shipments of chemicals. Water Handling Facilities received and stored water from the solvent washers, acid tanks, alkali tanks, floor drain tanks, and other sources. A Chemical Feed Building was in building 280-H. Building 244-H had Ion Exchange Regeneration, where resins used to remove radioactivity from the reactor basins were regenerated with sodium hydroxide and nitric acid. An Acid Recovery Unit concentrated nitric acid from approximately 5% to 50% for reuse. A General Purpose Evaporator concentrated low-level radioactive aqueous wastes. A Sump Collection Tank received waste condensate from sumps or tanks of the canyon air exhaust system, where it was sampled and sent to warm or hot canyon evaporators. A Recycle Sump collected drainage and overflow from all 211-H tanks and discharged the contents to the 501 skimmer. Target cleaning of aluminum-clad targets was accomplished with heated phosphoric acid and sodium dichromate. Segregated Solvent Facilities purified and stored used solvent (tributyl phosphate and diluent) that was recycled to the canyons for reuse (RAC, 1995). From 1978 to the mid-1980's building 235-F was used as a plutonium fuel facility producing plutonium oxide spheres sealed in iridium metal shells and plutonium oxide-aluminum billets (Bebbington, 1990).

Building 244-H contained the Receiving Basin for Offsite Fuels (RBOF) which starting in 1964 received spent SRS experimental and off-site fuel elements, and disassembled, inspected, and prepared them for delivery to canyon dissolvers, or stored them. The handling and storage was done remotely underwater. Along with the RBOF, there is an adjacent facility, the Resin Regeneration Facility (RRF). The water from the RBOF went through porous stone filters over to RRF where it was deionized. The RRF regenerated and decontaminated ion exchange resins used to purify water from the RBOF as well as water from the reactor area spent fuel disassembly and storage basins. The resins, which were not manually handled, were regenerated with sodium hydroxide, nitric acid and sodium nitrate. Also at the RRF there was chemical cleaning of irradiated reactor target elements prior to tritium removal, with phosphoric acid inhibited with sodium dichromate. The common ventilation system between RBOF and RRF moved from clean to potentially contaminated areas, and the air was treated before discharge (Hickey and Cragle, 1985).

Administration/Laboratory (700) Area

The Administration (or 700-area or A-area) consists of a number of very different facilities. The Department of Energy office, the Savannah River Ecology Laboratory, the Savannah River Laboratory (now the Savannah River Technology Center), the Administrative offices were located here (RAC, 1995). Building 773-A was the main laboratory building, containing metallurgical research and development facilities for experimental fuel and target elements, a multi-station laboratory that measured heat transfer characteristics, laboratories to develop more effective radiation nuclear monitoring instruments, an Isotopes Process Development Laboratory for encapsulating radionuclides, comprehensive laboratories for process and analytical chemistry which duplicated plant chemical separations on a small scale, chemical engineering, physics programs, technical shops and stores, a technical library, and offices (Bebbington, 1990).

Building 773-A also contained the High Level Caves for experiments conducted on highly radioactive materials. In the front of the caves the technicians worked using "master-slave" manipulators in order to remain away from the radioactivity. All transfers in and out of the experiment cells and equipment maintenance were done from the back of the cells (Bebbington, 1990). Air flowed from clean to contaminated areas, was filtered, and exhausted (Hickey and Cragle, 1985). An Integrated Supernate Processing Facility investigated, developed, and tested procedures for decontaminating high-level radioactive wastes using waste samples. A Californium-252 Production Facility, shut down in 1987, made neutron sources. A Medical Source Fabrication Facility, shut down in 1991, made Californium-252 needles for cancer treatment. Other research facilities included an experimental physics laboratory in building 777-M (now 777-10) with two experimental reactors and a test pile, a health physics laboratory in building 735-A for environmental monitoring and biomonitoring, an equipment engineering laboratory and shops in building 723-A, a separations laboratory in building 772-1F, and the original main analytical laboratory in building 772-F. Building 719-A was the central medical facility (RAC, 1995; Bebbington, 1990).

The A-area also included the CMX and TNX Technical Development Facilities near the 400 D-area. These were process pilot facilities, both beginning in 1953. CMX was a reactor support facility which investigated problems associated with using Savannah River water for cooling, and housed river water pumps, a pressure facility for testing reactor elements, a hydraulic test facility, and carried out long-term flow testing of new fuel and target assemblies. It was shut down in 1983. TNX provided technical support and development for separations processes, training personnel, and testing equipment performance using solutions of unirradiated uranium. In later years waste processing research and development was done, simulating waste processing with nonradioactive materials (Bebbington, 1990; RAC, 1995).

Building and road maintenance and construction was handled out of large, centrally located mechanical shops as well as about 50 smaller area shops. These included two stress-relieving furnaces that operate at 21000 F and a concrete batch plant. There are two pumphouses on the Savannah River and one at an artificial lake, and another at the heavy water area. Each Separations area has two separate well systems (Hickey and Cragle, 1985). Water treatment facilities operated at nearly all of the area sites. There are two fire stations, in buildings 709-A and 709-F (RAC, 1995). Each plant area has coal-fired power plants to provide steam and electricity there, as well as providing steam at five other locations (Hickey and Cragle, 1985).

Waste Management

In area F of Separations a laundry decontaminated and laundered items contaminated with radioactive material such as plutonium, neptunium, uranium, and fission products. Protective clothing too contaminated to launder was packaged and buried. The laundry waste water was transferred to a seepage basin if the radioactivity was low enough. Highly contaminated water was evaporated with the distillates sent to a seepage basin and the residues sent to a waste storage tank (Hickey and Cragle, 1985).

There are one hundred fifty-three waste disposal and storage sites at SRS. One hundred eighteen are for only non-radioactive materials, and 20 are for radioactive materials only (RAC, 1995). Waste management includes seepage basins for liquid wastes, sewage treatment and a sewage lagoon, disposal pits and waste piles for solid wastes, burning pits, acid/caustic mix and ash basins, and burial grounds for radioactive wastes. There are three types of radioactive waste from irradiated fuels: aluminum metal cladding that has been dissolved in sodium hydroxide and sodium nitrate, acidic wastes from fission products neutralized with sodium hydroxide, and fission products and aluminum waste from uranium-aluminum alloy fuel elements dissolved in nitric acid and mercury. Non-radioactive wastes include, among others, aluminum, iron, manganese, sulfur, sodium, potassium, and mercury (Bebbington, 1990).

There are twelve 750,000 gallon underground tanks, with eight in the F-area and four in the H-area. There are four 1,000,000 gallon tanks in H-area, which have been plagued by leaks due to the character of the waste solutions acting on stresses near welds. There are also thirty 1,300,000 gallon tanks. Finally, there are eight tanks, which hold the lowest-activity wastes. Four of these tanks were placed in the F-area in 1958 and four in the H-area in 1962. There is also a low-level solid waste burial site between 200-F and 200-H Separations areas (Bebbington, 1990).

Although environmental releases of contaminants (i.e., environmental releases onto soil and into ground water) may not be accurate indicators of exposures workers experienced, reports of releases do indicate such contaminants were used on site. Therefore, it is possible (but not proven) workers could have come in contact with these substances during process operations. The classes of contaminants found in soils and ground waters of the SRS complex include:

Class of Contaminant	Present in Soil	Present in Ground Water
Metals		
Anions		
Radionuclides		
Chlorinated Hydrocarbons		
Fuel hydrocarbons		---
Phthalates	---	
Polychlorinated biphenyls	---	---
Explosives		---
Ketones	---	
Pesticides		
Alkyl phosphates		---
Complexing agents		---
Organic acids		---

(Source: US DOE, 1992)

III. APPROACH

A multi-task approach was implemented to address specific objectives of this Phase I project:

Objective 1.

To determine if workers were exposed to harmful agents.

The investigators used multiple sources of information to evaluate the potential for workers to be exposed to harmful agents while conducting their occupational duties. In particular, we sought sources to identify industrial processes, known harmful worker exposures (radiologicals and chemicals of concern), releases of hazards, and occupational-related illness. The types of sources used included interviews with health, safety, and medical professionals at SRS; documents pertaining to SRS (reports on the history of SRS, accidental releases, safety audits, as well as journal articles about the health of SRS workers); industrial hygiene and medical records (including relevant databases); personnel information; and meetings with former SRS workers.

Objective 2.

To Determine Health Effects Workers Might Experience Due to Occupational Exposures

Once the hazards of concern were identified in Objective 1, the literature was reviewed to determine acute and chronic effects associated with each hazard listed. Chronic effects were of primary interest for this project, as most workers probably left the employment of SRS at least several years ago.

Objective 3.

To Determine Which Workers Were Exposed and How Many

Industrial hygiene, medical, and personnel records were reviewed to identify workers who were exposed to harmful agents. In addition to these records, knowledge of the processes and their locations were used in an attempt to construct job exposure matrices as well as risk maps. Use of these data sources and matrices provided a means to estimate the number of workers at risk for exposure.

Objective 4.

To Assess the Feasibility of Contacting Former Workers

A random sample of approximately 300 former workers was chosen to explore the feasibility of contacting former workers. The brief time between obtaining a list of former employees (6/22/98) and submission of this report prevented an extensive assessment of the various means to contact former workers. However, an assessment was made of the first attempt of contacting this group (use of phone directories available on Internet). Other means of locating these workers were identified for future reference.

Objective 5.

To Identify Approaches for Conducting the Project in Partnership with Relevant Groups

Attempts were made to contact former workers and to identify groups or individuals that would be interested in this project. However, the time we committed to obtaining exposure information as well as information that could be used to identify former workers did not leave time to develop a comprehensive approach to meet this objective at this time. We intend to meet this objective in the future.

IV. Sources of Information and Findings

A. History and Background

Three manuscripts were used to provide information on the history of the Savannah River Site, its facilities and processes. William P. Bebbington's (1990), History of DuPont at the Savannah River Plant, highlighted SRS events from before its being up to Du Pont turning over management of SRS to Westinghouse Savannah River Company in 1989. The manuscript provided insight to manufacturing processes associated with reactor operations, fuel and target fabrication, heavy water production, separations procedures, and waste management. Elements of Du Pont's SRS radiation monitoring and health protection programs were also discussed.

Hickey and Cragle (1985) presented a detailed overview of the SRS production processes that included heavy water production, separations, tritium production, reactor operations, and various auxiliary components. The investigators also discussed the methodology they used and results they obtained in identifying hazardous exposures (predominantly chemicals) SRS production employees were most likely to experience.

A report by the Radiological Assessments Corporation was written to document environmental releases of hazardous material from SRS facilities. Within this document is a section on the history and description of key processes at SRS, including the reactor, heavy water, reactor fuel and target fabrication, separation, tritium processing, and other facilities.

The findings of these documents were presented in section IIB of this report, Description of the Savannah River Site.

B. Description of SRS Records to Identify Former Workers

1. Personnel Files Database

Three major sources of personnel records were reviewed to identify former SRS workers. These data are: a set of electronic files provided by Donna Cragle (Cragle data), a box of hard copies of former SRS workers from SRS Human Resource (HR data), and a set of electronic files from SRS Medical Department. A description of each data base follows.

a. Cragle Data

The Cragle data were developed by Dr. Donna Cragle of Oak Ridge Associated Universities (ORAU) in 1989 for a mortality study among SRS workers. The data obtained from this source were found in eight data files, among which six contained personnel data.

1) HP AREA: contained records for 29,739 workers. The variables included in this file are: SSN, employee number, employee name, birth date, plant service date, health physics area, health physics department, supervisor location, employee status, and radiation measurements. In addition to data on radiation measurements, personal information, such as SSN, name, birth date, health physics area, health physics department, and employee status, was used to estimate the number of former workers.

2) Death Data: There are 2,761 records in this file. The DEATH file contains the SSN of all persons for whom Cragle had obtained a death certificate.

3) Demographic Data: There are 21,468 records in this file - one for each person listed. This file contains SSN, race, gender, and birth date.

4) Employment Data: There are 28,207 records in this file. The variables in this file are SSN, facility code, hire date, and termination date.

5) Name Data: This file contains all names of workers known from 1952-1989. There are 21,996 records in the file. It has SSN, last name, first name, and middle name for each person.

6) Vital Status Data: This data file tracked the life status for 18,741 workers during 1982 through 1997. The file contains three variables (SSN, Status, and Date) and has 68,183 records. Among the workers listed in the file, 1,510 died, two were indicated as "alive" and 17,229 were indicated as "unknown" at the last time their status was recorded (most were in 1996 or 1997).

By combining several of Cragle data files, a new data set was created by the researchers that contained people alive in 1989 as well as people having their most recent termination occurring in 1989 (if they had multiple terminations). This data combined all personal information available from the Cragle data, which consisted of SSN, name, sex, race, birth date, hiring date, and termination date for 12,642 SRS workers.

b. Human Resource (HR) Data

These data are composed of three files: Exemptions, Terminations, and Pension data. All data have SSN, name, and termination date. The Exemption data listed 5,816 names terminated during 1951-1991. The Terminations data contained names and SSN for 8,855 persons terminated during 1989-1995. The Pension data were created in 1992 and contained records for 14,753 workers who were terminated during 1954-1989.

From April 1989 forward, Westinghouse Savannah River Company kept a personnel file on its workers called TESSERACT. The data we sought from this database included terminated or retired workers' names, social security number, gender, race, date of birth, hire date, termination date, job titles, department worked, and date of death (if deceased). We requested this data from SRS, but as yet, have not received it. We will update this section if and when we receive this data.

c. Medical Records Database

The Medical Records Database is potentially the most complete data source in terms of identifying former workers at the SRS. The individual file names within this source and associated population numbers are listed below:

Pensioners – 3,085
Terminations –19,677
Deceased – 2,084
Unspecified - 734

Total – 25,580

From these files, we believe the population of former workers is approximately 20,000 individuals. We received a copy of this data on 6/22/98. Limited analysis was done on the data; however, additional analysis appears in Section VIII (Medical Surveillance for Former SRS Workers) of this report.

Also the Tickler data have 27 files for 1,180 workers enrolled in 12 Surveillance/Qualification Programs at SRS. These programs are:

Asbestos
Benzene
Enhanced Fitness for Duty
DOT drivers
Laser Worker
Firefighters
Hazardous Waste Workers
Surveillance/Qualification Program
Hearing Conservation Program
Blood Lead Surveillance
Personnel Security Assurance Program
Liquid Effluent Treatment Facility

Workers were listed under one of four categories in each program: Operating Contractor terminations, Deceased, Construction terminations, and Pensioners. Nine hundred eighty names were listed as Operating Contractor Terminations and Pensioners. The data contain SSN, name, badge number, exam date, special test, and substance. The time of examinations was between 1984 and 1997.

V. Description of SRS Records to Identify Hazardous Exposures

A. Radiation Hazards

a. Radiation Exposure Databases

In 1979, the SRS developed a number of databases for the management of radiation doses received by radiation exposed workers. Prior to 1979, monitoring records were kept in hard copy form. Approximately 75,000 employees have radiation monitoring results maintained at SRS both in database and hard copy form. The radiation doses of SRS workers that were still employed in 1979 were transferred from the hard copy to the electronic database format. If a worker terminated employment or retired prior to 1979, their dose history is found only in paper records.

The Health Physics Radiation Exposure Database (HPRED) contains external radiation dose readings from personnel dosimeters and internal dose readings from bioassays and whole body counts. This database also contains information on each employee's age, sex, date of hire and job location. Radiation doses for the current year are accumulated in HPRED. In addition, data from the previous year is maintained here. At the end of each calendar year, the previous year's data are dumped into an archival database called the Health Physics Archival Exposure History (HPAREH). HPAREH contains only the annual total radiation dose for each worker and not the doses for the monthly intervals. HPAREH contains doses to employees of the prime contractor at SRS and employees of its various subcontractors which perform work onsite.

An additional database was developed to monitor the doses employees received prior to employment at SRS and to monitor doses of current employees working offsite (usually at other DOE locations). This database is called POETS (Previous and Offsite Exposure Tracking System). POETS is a subset of HPRED.

In 1985, an additional database called HVIS was developed to monitor the radiation doses of visitors who work onsite for short periods (1 week to 3 months). HVIS is an archival database and is a subset of HPAREH. HPAREH contains dose history data for approximately 70% of all the radiation exposed workers who were ever employed at SRS. It is believed that about 20,000 former workers have doses maintained in the hard copy files. HPAREH includes 54,299 SRS workers. Of those, 39,655 have been monitored for external dose. The remainder have either been monitored for internal exposure at SRS, received radiation dose at another nuclear facility or entered into HPAREH as an employee of the prime contractor but were never monitored at SRS.

Tritium is included in external whole body doses at SRS since it exposes all tissues to the body. No other internal exposures are included in the external dose.

Internal dose data was maintained on index cards from the 1950's to 1984.
Since 1979, bioassay data for tritium has been automatically added to HPRED. Bioassay

data for all other monitored isotopes were automatically added to HPRED beginning in 1984.

The following table lists the cumulative external dose ranges recorded in HPAREH and the number of individuals in that range. Tritium is included in external whole body doses at SRS since it exposes all tissues of the body.

Cumulative External Dose (mrem)	**Number of Individuals**
0	7714
1-24	7915
25-49	3858
50-74	2223
75-99	1445
100-199	3192
200-299	1674
300-399	1224
400-499	941
500-599	731
600-699	606
700-799	511
800-899	435
900-999	394
1000-1999	2280
2000-2999	1068
3000-3999	672
4000-4999	400
5000-9999	992
10000-14999	485
15000-19999	339
20000-24999	241
25000-29999	171
30000-34999	94
35000-39999	47
40000-44999	15
45000-49999	6
>50000	0

Proportion $\geq$ 20 rem = 574/39673 = 1.4%

1. Data for external and internal worker dose at SRS was provided by Dr. Kenneth Crase, Technical Advisor, WSRC.

The following table categorizes the number of individuals with doses above a given external dose:

Cumulative External Dose (mrem)	Number of Individuals
>50000	0
>35000	68
>25000	333
>10000	1398
>5000	2390
>1000	6810
>500	9469
>100	16500
>50	20168
>25	24026
>0	31941
=0	7714

1.Data for external and internal worker dose at SRS was provided by Dr. Kenneth Crase, Technical Advisor, WSRC.

The median cumulative external dose to these workers is 50 mrem. This is due to the fact that 7,714 of the monitored workers received zero external dose. No worker at SRS has ever received as much as 50,000 mrem cumulative external dose. Only three workers have ever received more than 5,000 mrem from external exposures (including tritium) in a given calendar year.

The following table is a summary of internal radiation doses (CEDE) received by SRS workers from intakes of radionuclides other than tritium. The data includes all known SRS intakes to workers above 10 mrem CEDE. This summary may be somewhat incomplete due to the changes in methodologies of assessing internal dose by regulatory agencies. Prior to 1985, internal doses were determined and compared to the Maximum Permissible Body Burden (MPBB) for each radionuclide. Intakes that were less than 10% of the MPBB were not always tracked. In 1985, the SRS began to assess doses from radionuclide intakes and reported them to the affected workers. They also assessed dose from all know historic intakes at that time.[1]

Internal Dose (CEDE, in mrem)	Number of Workers
200,000 - 249,000	1
150,000 - 199,999	1
100,000 - 149,999	1
90,000 - 99,999	1
80,000 - 89,999	1
70,000 - 79,999	2
60,000 - 69,999	6
50,000 - 59,999	1
40,000 - 49,999	4
30,000 - 39,999	4

25,000 - 29,999	5
20,000 - 24,999	11
15,000 - 19,999	19
10,000 - 14,999	31
5,000 - 9,999	95
4,000 - 4,999	46
3,000 - 3,999	65
2,000 - 2,999	90
1,000 - 1,999	153
500 – 999	138
250 – 499	90
100 – 249	121
50 – 99	70
10 – 49	83

Proportion $\geq$ 5 rem = 183/1039 = 18%

1. Data for external and internal worker dose at SRS was provided by Dr. Kenneth Crase, Technical Advisor, WSRC.

The following table categorizes the number of individuals with doses above a given internal dose:

Internal Dose Range (CEDE, in mrem)	Number of Individuals
>100,000	3
>50,000	14
>25,000	27
>10,000	88
>5,000	183
>1,000	537
>500	675
>100	886
>50	956
>10	1,039

1. Data for external and internal worker dose at SRS was provided by Dr. Kenneth Crase, Technical Advisor, WSRC.

b. Fayerweather Database

The Fayerwether Database was used by Dr. Donna Cragle of Oak Ridge Universities Association to conduct epidemiology studies on workers exposed to radiation during their employment at SRS. The database consists of 221,330 records for radiation measurements among 8,195 SRS workers during 1952 through 1978. The Fayerwether file included workers' SSN number that can be linked to other Cragle data for workers'demographics. Most of the workers in the data set were white (7,090 or 87%) and male (6,267 or 76%). The radiation measurements included in the Fayerwether file are "year reading open window", "year reading shielded", "year reading tritium", "year reading neutron", "plant reading open window", "plant reading shielded", "plant reading tritium", and "plant reading neutron" in 27 years. Table 1 shows cumulative radiation readings that were based on the sum of annual radiation readings for each worker included in the data set.

Table 1

Fayerweather Data (8195 workers between 1952-1978)

Open Window	Frequency	Percent	Cum. Freq.	Cum. %
0	2559	31.2	2559	31.2
1-9999	4929	60.1	7488	91.4
10000-	253	3.1	7741	94.5
15000-	134	1.6	7875	96.1
20000-	100	1.2	7975	97.3
25000-	56	0.7	8031	98.0
30000-	164	2.0	8195	100.0

Shielded	Frequency	Percent	Cum. Freq.	Cum. %
0	2673	32.6	2673	32.6
1-9999	5226	63.8	7899	96.4
10000-	155	1.9	8054	98.3
15000-	76	0.9	8130	99.2
20000-	40	0.5	8170	99.7
25000-	12	0.1	8182	99.8
30000-	13	0.2	8195	100.0

Tritium	Frequency	Percent	Cum. Freq.	Cum. %
0	7615	92.9	7615	92.9
1-9999	578	7.1	8193	100
10000-19000	2	0.0	8195	100

Neutron	Frequency	Percent	Cum. Freq.	Cum. %
0	7781	94.9	7781	94.9
1-9999	414	5.1	8195	100.0

Partial Body Dose vs. Whole Body Dose

It should be noted that the distribution of doses to the body from external radiation sources can be quite different from the distribution of doses that occur as the result of intakes of radionuclides by the body. Doses from fairly uniform, external radiation fields are distributed over the whole body (head, neck, trunk, upper arms and legs). Whereas, radionuclides that enter a living system through inhalation, ingestion or absorption may be distributed evenly throughout (in the cases of tritium, carbon-14 or cesium-137) or they may accumulate in certain target organs. For instance, the thyroid gland will accumulate atoms of radioactive iodine. The bones will accumulate radioactive phosphorus, strontium or plutonium.

In addition, certain respirable fractions of radionuclides may become lodged in the deeper recesses of the lung and have a very long residence time in the pulmonary tissue. In this case, radiation emitted from high LET sources, such as plutonium and other alpha emitting sources can impart a significant local dose to the tissue immediately surrounding the radiation source. This situation could eventually result in a biological effect being manifested. Individuals receiving a significant internal dose may require continued medical monitoring.

Possible Effects Related to Heterogenous Irradiation Fields

Radiation workers are often exposed to uniform homogenous sources of radiation from various plant processes. The doses incurred by the workers are measured with a personnel dosimeter and the amount of dose received is noted in the worker's personal exposure history. However, workers engaged in certain types of activities may receive doses that are more difficult to quantitate. Hot particles can be generated in fuel fabrication, reactor operations and in reprocessing activities. Hot particles (also known as fleas or specks) are microscopic particles that contain beta/gamma emitting radionuclides.[1]

Hot particles can be generated from fuel cladding. Fleas are very dense and are highly mobile. Due to their electrical charge, they can be easily transferred from one surface to another. They can stick to clothing and have the potential to impart a significant local dose to the skin from the highly energetic beta radiation emitted. In addition, a hot particle could be transferred from the hand of a worker to the eye, ear or mouth. Airborne fleas could also be inspired and deposited into the respiratory tract or mouth.[2]

In the course of a month, a worker's personnel dosimeter may indicate radiation exposure within regulatory limits but the individual may have received a significant, intense local dose due to the presence of a hot particle. Possible health effects due to exposure to hot particles include microlesions of the skin which would appear shortly after exposure. In addition, the area of exposure would be subject to long term effects such as skin cancer or lung cancer (if particle is inspired).

During the past few years, highly sensitive personnel monitoring equipment has been installed at nuclear facilities and hot particles are now more easily detected. But for many years, hot particles were probably present but not detectable and health physics personnel may not have been sensitive to the symptoms of hot particle exposure.

1. Scott, B.R., A Generic Model for Estimating the Risk of DeterministicEffects of Partial Organ Irradiation by Hot Particles.Health Physics Vol 69(6): pp 909-916.
2. Gollnick, D., Basic Radiation Protection Technology, Second Edition Pacific Radiation Corporation, 1988, page 581.

B. Non-Radiological Exposures

1. Existing Reports

a. Hickey and Cragle (1985)

The most useful existing report for examining potential chemical exposures to employees was the report by Hickey and Cragle (1985) referred to above. The purpose of this report was to evaluate the potential occupational hazards presented to the production workers at SRS for the years 1952-1984. The investigators constructed an exposure profile from plant processing descriptions and records, job title records, and published reports. Due to the lack of airborne dust or chemical sampling records or other direct exposure assessments, the researchers' judgement played a large role in the evaluation. The criteria used to select a priority list of chemicals of concern included the relative toxicity of the material from inhalation exposure; relative quantity of the substance used or produced; opportunity for worker exposure; indication from plant personnel records or in processing descriptions and instructions that the substance was an exposure hazard; air monitoring information indicating substantial quantities of the substance were present; biological monitoring data indicating substantial body burdens of the material in employees; indications that efforts were made to control and monitor worker exposure to the substance; judgement of the investigators; and practical limitation on the number of materials which can be studied for health effects. Nine substances were found to be of a toxic nature as well as having a high likelihood for worker exposure. These substances were hydrogen sulfide gas, nitric acid and nitrous vapors (NOx), fluorine compounds (HF, F_2, F salts), sulfuric acid and sulfur oxides (SOx), mercury and mercuric compounds $(Hg(NO_3)_2$, tributyl phosphate (TBP) and dilutent (kerosene), oxalic acid, phosphoric acid, nickel and nickel compounds. The authors also listed additional substances they considered of lesser concern (see Table 2), as well as chemical hazards that can be found in various production facilities (see Appendix 1).

Table 2

Nine Chemicals of Major Concern for Employee Exposure and Alternates as Identified by Hickey and Cragle (1985)

Nine Chemicals of Major Concern

Fluorine compounds (HF, F_2 , F salts)
Hydrogen sulfide gas
Mercury and mercury compounds
Nickel and nickel compounds
Nitric acid and nitrous vapors
Oxalic acid
Phosphoric acid
Sulfuric acid and sulfur oxides
Tributyl phosphate (TBP) and diluent (kerosene, dodecane, m- and n-deodecane)

Substances of Note

Asbestos
Ferric sulfamate
Hydrazine mononitrate
Lithium and lithium compounds
Perchloroethylene
Sodium dichromate
Sodium hydroxide

b. Catalog of Industrial Hygiene Reports and Industrial Hygiene Reports

A printout of the industrial hygiene reports available at SRS was obtained and reviewed. This record indicated contaminants that were sampled by industrial hygienists and the location, typically by building number, where the sample was taken for the years 1984-1989. This information was used to construct Table 3, which shows the 200 (separations), 300 (fuel and target fabrication), and the 700 (administration and laboratories) areas having the most industrial hygiene related activity. Appendix 2 shows that the activity in the 200 and 300 areas are concentrated in a few facilities (221f, 221h; 313m, 320m, 321m), while being more diffuse in the 700 area. Appendix 3 shows that asbestos and existed across the site. Noise hazards predominantly occurring in power facilities. (Appendix 4)

Table 3
IH Sampling Conducted at SRS by Facility Area

Chemical	100	200	300	400	600	700	Shops	Unknown
Acetate Xylene								x
Acetic Acid						x		
Acid Mist			x					
Aluminum/Aluminum Oxide			x					
Ammonia							x	
Asbestos	x	x	x	x	x	x		x
Benzene					x			x
Boric Acid		x						
n-Butyl Acetate						x		
Carbon Monoxide		x				x		
Chromium					x			
Coal Dust	x	x		x				x
Crystalline Quartz				x	x			x
di (2-ethylhexyl phthalate)						x		
Dioxane			x					
DOP								x
Epichlorhydrin								x
Fiber Glass						x		
Freon		x	x					
Heat Stress		x		x		x		
Hexanol								x
Hydradzine mononitrate		x						
Isopropyl Acetate						x		
Kerosene						x		
Lead			x			x	x	x
Lithium			x					x
Metal Fumes						x		
Methyl Chloroform			x					
Methyl Isobutyl Ketone						x		
Methylene Bisphenyl Isocyanate						x		x
Methylethyl Ketone						x		
4,4 Methyldianiline		x						
Methylene Chloride		x	x					x
Mercury/Mercury Compounds		x			x			
Mineral Spirits	x							
Neptunium -- spelling		x						
Nickel			x					
Nickel Sulfate			x					
Nitric Acid		x	x					
Nuisance/Total Dust			x				x	x
Oil Mist	x	x	x			x	x	
Oxalic Acid	x	x				x		
Oxides of Nitrogen		x	x					
Perchloroethylene	x					x		
Petroleum Naptha						x		
Phenol					x			x
Potassium Permanganate		x						
Plutonium		x					x	
Polycylic Chlorinated Biphenyls (PCBs)								x
Refractory Ceramic Fibers		x	x			x		x
Sodium Hydroxide			x		x			
Sodium Nitrate		x						
Styrene		x				x		x
Toluene-2,4-diisocyanate						x		x
Total Hydrocarbon								x
Total Particulate			x			x		
Tributylphosphate		x						
Trichloroethane	x	x	x	x				x
Uranium/Uranium Compounds		x						
Wood Dust							x	
Welding Fumes		x				x		
Xylene						x		x
Zeolite Dust								x

Industrial hygiene records found at SRS also were reviewed. These documents were found on microfilm, and for the most part, provided little information that could be used in this assessment. While it seemed most monitoring results were low, the documentation provided too little detail to draw inferences about exposures to production employees. Most records gave no or little detail as to the nature of the monitoring conducted (e.g., duration, process, employee identification, job task, interpretation of results), and thus, these records provided little insight beyond the industrial hygiene report catalogue.

c. DOE Tiger Team Report on SRS

The DOE Tiger Team Report documented an assessment conducted from January 29 to March 23, 1990 on the status of Environment, Safety and Health Programs at SRS. The assessment focused primarily on management and administrative issues, but to a lesser extent, did address compliance issues related to occupational health as well. Overall, the assessment did not find any problems at SRS that presented an undue risk to public health or the environment. An occupational health and safety audit by the Tiger Team found 288 items of concern; however, none posed a clear and imminent danger to workers or the public. The types of violations found were as follows: electrical hazards (37%), personal protective equipment (11%), hazard communication (10%), machine guarding (8%), walking/working surfaces (6%), and compressed gas storage (6%). Of particular relevance to our project, the Tiger Team noted a lack of a comprehensive, site-wide safety and hazard evaluation at the time of their audit (SRS Tiger Team Report, 1990).

2. Databases

a. Inactive Facility Database

A list of inactive facilities that describe the potential hazards found in the facility was reviewed. For the most part, this database was not useful for our project. The database described existing hazards in 100 facilities. Because these facilities are no longer used for production purposes, the existing hazards will often differ from those that existed when the facility was operating.

b. Risk Assessment Reports

A risk assessment program is in place at SRS that covers practically all processes including production, laboratories and various support services. The assessments are performed by the industrial hygiene division. An industrial hygienist developed a list of hazards associated with each process and then assessed the level of exposure that every work group may have to each hazard. Assessment reports are generated for each hazard and entered into the Facility Assessment Database (FAD). The reports have two formats. The first one is titled the Qualitative Risk Assessment (QRA) form. This form provides a detailed description of each hazard and includes:

(1) the work hazard (chemicals, noise, asbestos, etc.)
(2) the particular chemicals of concern
(3) the work group affected by the hazard
(4) a description of the operation where the hazard exists
(5) the duration of the task
(6) the amount of material used
(7) a list of engineering controls associated with the process
(8) a list of administrative controls
(9) personal protective equipment used
(10) a list of work practices
(11) potential exposure pathways
(12) target organs impacted by hazard.

On the back of each QRA form, a qualitative exposure rating is given by the industrial hygienist. Five categories of exposure are listed: no exposure, low exposure, moderate exposure, high exposure and very high exposure. In addition, the industrial hygienist rates the qualitative health effect of each hazard: no adverse health effects, reversible health effects, severe reversible health effects, irreversible health effects and life threatening or disabling injury or illness.

The second format comes from the Task Window of the Facility Assessment Database. It does not have the same level of detail as the QRA forms. It contains the following information:

(1) location and date of assessment
(2) the job classification
(3) the hazard
(4) the engineering controls in place
(5) the administrative controls
(6) personal protective equipment needed for job.

It should be noted that the risk assessments can become obsolete as processes change and production improvements are instituted. However, this information does unite individual workplace hazards with specific job descriptions and can be a valuable source of information when trying to assess long-term health effects in the workplace. An example of a QRA report can be found in Appendix 5. Although this was a data source that provided much information, we only had access to two areas and not the remainder of the site. Further, this database is relatively recent; therefore, data on previous production activities (now ceased) would not be included.

c. Occurrence Reporting Processing System (ORPS)

In 1990, the U.S. Department of Energy developed a program known as the Occurrence Reporting Processing System (ORPS) that was designed to notify DOE's central office of each significant event that occurs at the various DOE sites throughout the country. A significant event would include malfunctioning equipment, personnel contamination, exposures to chemicals, injuries and accidents with equipment, deaths of any kind (related or unrelated to SRS activities) and environmental degradation. ORPS also has a protocol for notifying the emergency response organizations in the local community of a serious incident. This program also requires each DOE facility to develop corrective action to reduce the likelihood of a repeat event.

The ORPS program was instituted at SRS in 1991; therefore, since this time a report has been generated for any incident that is deemed to be significant. Each event is classified into two categories: (1) unusual event - which requires immediate notification of DOE Headquarters and (2) off-normal event - less serious but still requires notification and corrective action. At SRS, approximately 90% of reportable events are off-normal and 10% are unusual.

An Occurrence Report contains the identities of various individuals that were notified of an event and a detailed description of the event. In addition, the report describes the immediate actions that were taken as well as the results of the action. A description of the cause is included. Each event is also analyzed for its impact on the environment and health and safety. The report also includes a list of codes or standards that have been violated.

The ORPS database at SRS was reviewed in the following areas:

(1) radioactive contamination to personnel
(2) chemical exposures
(3) exposures to asbestos
(4) noise problems
(5) heat stress

d. Tickler Data (from Medical Records)

The Tickler data (described above) provided information of specific occupational hazards for which employees participate in a medical surveillance program. These programs included:

Asbestos
Benzene (note -- workers transferred from a plant where they were exposed to benzene)
Lasers
Hearing Conservation Program
Blood Lead

e. E-Codes from Medical Records

Chemicals and hazards identified by the E-Codes on medical records indicated the following were exposures of concerns at SRS:

Asbestos
Dioxane
Hydrazine

Hydrogen sulfide
Lasers
Neutrons
Perchloroethylene
Polycyclic chorinated biphenyls
Transuranium radionuclides
Tritium

C. Data Quality

With the exception of medical records and radiation monitoring, few of the data sources discussed above allowed for the linkage of individual employees with specific non-radiological exposures. Neither was there linkage between individuals and specific work locations or processes. In regard to the industrial hygiene records these investigators reviewed, the proportion of personal samples taken per number of total employees was very small. The time period when most personal samples were taken typically occur from the mid-to-later 1980s forward. Personal samples taken during asbestos abatement activities were the most common type, a process or exposure situation that most production workers would likely not experience. For other non-radiologicals agents, it is unlikely that valid estimates of exposure could be derived from extrapolating the results of the few (if any) personal samples that were available for review. One would obviously question the representativeness of such samples. Therefore, only a qualitative assessment (as opposed to a quantitative) of exposure can be derived from most data sources.

VI. Epidemiology Studies/Activities at SRS

A. Epidemiology Studies/Surveillance

1. Cragle et al. (1988)

These investigators conducted a historical cohort mortality study of white, male workers employed at SRS between 1952 and mid-1981 who produced nuclear fuels and other materials. The results of 6,697 hourly employees and 2,745 salaried employees showed a mortality experience similar to the US population, and actually showed fewer than expected deaths in many categories, including all causes, all cancers, cancer of the digestive organs, lung cancer, brain cancer (hourly workers only), diabetes, all diseases of the circulatory system, all respiratory diseases, all digestive system diseases, all diseases of the genitourinary system (hourly workers only), and all external causes of death. However, an unexplained statistically significant increase in leukemia deaths was observed (6 observed, 2.18 expected) in a subset of workers hired before 1955 and who worked between 5-to-15 years.

2. An unpublished update of the 1988 Cragle study (above) was reviewed from DOE CEDR files (DOE CEDR. Savannah River Cohort Morality Study. (HYPERLINK http://cedr.lbl.gov/cgi-bin/spiface/find/cedrdfs http://cedr.lbl.gov/cgi-bin/spiface/find/cedrdfs), a study based on deaths through 1986 for a total of 290,000 person-years of follow-up. This study included radiation dose in the analysis. For hourly workers there were 19 leukemia deaths, resulting in an SMR of 1.34 with a 95% confidence interval from 0.80 to 2.09. The healthy worker effect reported in the previous study was still evident as SMRs were significantly below one for all causes (0.78) and all cancers (0.82). With the exception of leukemia, a dose-response association between radiation dose and cancer (all cancers, lung, leukemia, colon, and pancreatic) was not found. However, this dose-response relationship was based on only 20 leukemia deaths, including two nonunderlying causes of death and excluding chronic lymphocytic leukemia, which has not been linked to radiation exposure.

3. DOE Epidemiologic Surveillance at SRS

a. Epidemiologic Surveillance – 1994

Epidemiologic surveillance at U.S. DOE facilities involves regular and systematic collection, analysis, and interpretation of data on absences due to illness and injury of workers. Data are collected by coordinators at each site and submitted to a central location. Rates of absences and rates of diagnoses associated with absences are analyzed by occupation and other relevant variables.

The highest diagnostic group rate (all rates reported are age-adjusted to 1970 U.S. population) for illnesses and injuries among all SRS workers for 1994 were diseases for the respiratory system (74.8 per 1,000); followed by symptoms, signs, and ill-defined conditions (30.8 per 1,000); and diseases for the musculoskeletal system (28.8 per 1,000) (see Appendix 6). Appendix 7 shows the rates for diagnostic groups reported for males. For men, the highest diagnostic group reported was for diseases of the respiratory system (54.5 per 1,000), then musculoskeletal diseases (25.7 per 1,000), followed by diseases described as symptoms, signs, and ill-defined conditions (19.7 per 1,000). Fifteen cancers were diagnosed in 1994. The organ reported most for cancer were the prostate (2 cases) and the rectum (2 cases). Appendix 8 shows the rates for diagnostic groups reported for females. As with men, respiratory diseases also were the highest reported diagnostic group for females (134.9 per 1,000); followed by symptoms, signs, and ill-defined conditions (69.6 per 1,000). Fourteen cancers were reported among women, breast cancer was the most common (n=5). Three diagnoses were reported for Hodgkin's disease, two for carcinoma in situ of cervix uteri.

In general, the data in Appendices 6-8 do not show anything unusual with the health of the SRS workers.

B. Workers Compensation Records

The South Carolina Workers Compensation Commission has computerized claims records from 1983 (inclusive of 1983) to the present. This data set showed approximately 1500 individual claims originating from the SRS. These claimants worked for several different employers including Dupont, Westinghouse, as well as several subcontractors (i.e., BF Shaw, Morrison Knudsen, North Brothers, Becktel, MK Ferguson, Wackenhut, and several others).

The file has limited usefulness except to show the number of work related health problems severe enough to cause an individual to file a Workers Compensation claim. The categorization of the claims was done according to vague descriptions that continue to be used by the South Carolina Workers Compensation Commission. This categorization method makes it very difficult to determine exactly what was the basis of the illness or injury. For instance, cause number 12 was listed as "drowning, asphyxiation, or poisoning". Of course, this project would be very interested in the poisoning and possibly the asphyxiation group, but not be particularly interested in the drowning category. It would be impossible to determine how many of the records categorized as number 12 were actually caused by drowning. Of note, the most frequent claim was coded as "striking against".

C. Additional Sources of Information

1. Phone Survey of Former SRS Workers

A list of names and addresses of 88 SRS retirees who participated in biannual medical examinations offered by SRS was obtained, and these people were contacted by telephone to participate in a brief survey. Those who agreed to participate in the survey were asked if they knew of any exposures while employed at SRS that might have affected their health. They were also asked to identify specific exposures (see Appendix 9).

The ability to contact workers was assessed, and these results are shown in Table 4. This analysis shows that approximately 13% (n=11) of subjects contacted did not choose to participate in the survey. Forty-seven percent (n=41) participated in the survey, one of which terminated the interview. Two of these respondents indicated that they had not worked at the Savannah Rivers Site. Phone numbers could not be determined for approximately 24% (n=21) of the subjects. Eight percent of the calls reached persons (n=2) who could not communicate due to impairment or those individuals who are deceased or no longer at the address we were provided (n=5).

Of the thirty-nine respondents who did complete the telephone survey and had worked at the Savannah River Site, six (15%) indicated that they had health problems related to their work at SRS. Five of these six said they had health problems related to plutonium, one said they had heart problems. Twenty of the 39 (59%) respondents indicated that they were concerned about their occupational exposures while employed at SRS. Eighteen of the twenty (90%) were concerned about plutonium exposure, while two (10%) were concerned about radiation exposure.

Table 4
Telephone Survey of 88 Former Workers: Assessment of Process to Date

Outcome	No. of Calls (%)
Completed Interview	41 (47%)
Phone Number Not Found	17 (19)
Refused to Participate	11 (13)
No Eligible Respondent at Residency	5 (6)
Phone Was Busy (on more than 5 tries)	4 (5)
Non-Working Phone Number	3 (3)
Unreachable to Date	3 (3)
Subject Could Not Respond Due to Impairment	2 (2)
Phone Number Was for A Business	1 (1)
Terminated During Interview	1 (1)

1. Public Meeting with Former Workers

In order to better understand the perception of the former workers about their potentially hazardous exposures during employment at the Savannah River Site, an advertisement was placed in the Aiken and Augusta newspapers asking former workers to attend a meeting at the USC Aiken Campus to discuss the former workers health project.

A self-selected group of twelve former SRS workers attended the meeting. A list of individuals who attended is included in Appendix 10.

Dr. Adcock introduced the researchers and briefly described the project. A questionnaire (see Appendix 10) was distributed. Dr. Adcock informed the workers that there was no guarantee that their responses to this questionnaire would be kept confidential, and they were under no obligation to answer any of the questions. The survey included five questions about their work-related hazardous exposure and their current state of health. A summary of the completed surveys is included in Appendix 10. Dr. Zurosky then talked about some of the specific exposure hazards that the project would study and the databases that contain the exposure information.

From this discussion, the researchers learned:

- The former workers consistently indicated that the chemical and other hazardous agent exposures (excluding radiation) were not adequately monitored in the early days of SRS operation. They believe that only a small subset of the total exposed population were in any way monitored and any measurements that were made were probably not adequate to accurately record the exposure.

- There was a common belief that individuals were unaware of what hazardous substances and agents may have been in the work environment. They were concerned that there were mixtures of hazardous materials and that these were inadequately categorized and, particularly during the early days of production at the SRS, individuals were not adequately protected against exposure either by engineering controls or personal protective equipment.

- There were several questions which indicated some concern that there was no on-going monitoring of the potentially exposed population.

- Several of the former workers expressed displeasure about the discontinuing of physicals and would like to see them reinstated. The individual discussants all expressed concern that the post-retirement physical examinations done at the SRS had been discontinued in 1997.

- There is an organized retiree's association of approximately 1200 members. Tom Greene of North Augusta is the association's president. If a Health Risk Appraisal (discussed in Medical Surveillance Section of this report below) is made available to former workers as a result of this project, a questionnaire could be distributed in the association's quarterly newsletter to determine who would take advantage of the Health Risk Appraisal. Another group of loosely organized retirees meets for lunch at Ryan's on Whiskey Road the first Wednesday of every month.

VII. Specific Hazards and Possible Health Outcomes of Former SRS Workers

A. Ionizing Radiation

1. Radiation Exposure

The primary purpose for the development of the Savannah River Plant (Site) was to produce two products, tritium and plutonium, that were used as fuel for atomic weapons. Both of these products are a potential radiation hazard. Plutonium and tritium are produced in strong neutron fields in nuclear reactors. The reactor fuel, uranium-235, and the various mixed fission products are also radiation hazards. Radioactive materials were associated with the following processes at SRS:

a. nuclear reactors - five reactors R, P, L, K, C (100 areas)
b. separation and purification of uranium and plutonium - F and H areas (building 200 areas)
c. separation and purification of tritium - F and H areas
d. fuel and target fabrication (300 M Area)
e. liquid waste storage tanks.

The highest radiation fields were associated with the nuclear reactors. However, the reactors are constructed with highly reinforced concrete, which acts to shield the radiation, and make the reactors bomb-proof. As a result of construction practices, radiation doses to reactor employees would predictably be low. The areas of highest personnel exposure to ionizing radiation would probably be found in the separations facilities. In these facilities, airborne and skin contamination is possible. In the F Area (canyon), uranium and plutonium were recovered using the Purex process. The irradiated fuel rods were dissolved in a solution of nitric acid and sodium hydroxide. The three fuel rod products were:

(1) uranium - which was treated with a product (TBP) and converted to uranium nitrate. The uranium nitrate was denitrified outside the canyon and converted to uranium oxide.

(2) plutonium - which was concentrated by an ion exchange process and converted to a fluoride salt. Calcium was added and resulted in the production of plutonium metal.

(3) fission products - treated by ion exchange and separated from plutonium and neptunium. The fission products were transferred to holding tanks for storage.

Tritium was produced in three different processes at SRS. The greatest production came from the neutron irradiation of the lithium cladding covering the fuel rods. The tritium was separated from helium in vacuum furnaces and used as a weapon fuel source. Tritium was also produced in the reactor by the neutron irradiation of deuterium. It was released to the atmosphere. Tritium was also a product of the fission process and was either released to the atmosphere during reprocessing or converted to tritiated water. SRS employees were monitored for tritium by urinalysis.

The fuel and target element plants were located in building 320M. Bare uranium fuel rods were produced at the Fernald plant in Ohio and shipped to SRS. Each rod consisted of a 1 inch by 8 inch slug. The fuel rods were slipped into the aluminum cladding at SRS and bonded by immersion into a molten bath of aluminum and silicon. The end of the cladding was sealed by an end weld. Radiation dose to SRS workers from this process appears to be minimal since the fuel rods were manufactured elsewhere. Radiation exposure is possible in the handling of the rods.

Large tanks with a capacity of 750,000 gallons store liquid mixed fission products. Each tank is constructed of half-inch thick carbon steel in a cement vault. The tanks are subterranean and covered with nine feet of soil. Concrete lined tunnels provide access to the interior of each tank for cooling and inspection purposes. Due to the nature of the construction, radiation dose to employees is minimal. Inspectors who must traverse the tunnels would have the greatest chance of a significant dose.

A number of processes are still active at SRS including tritium replenishment of nuclear weapons, plutonium storage, the two canyons for reprocessing and spent fuel storage from Europe. Radiation monitoring is continuing for employees working at these sites.

2. Radiological Health Outcomes

External radiation is primarily gamma and its health effects are the same as x-ray. Most cancers can be induced by a single exposure with leukemia being the most inducible cancer type. Radionuclides produce primarily alpha with some beta radiation. These materials generally need to be injested to cause harm. This is due to the limited penetration by alpha particles in biological tissue. Each radionuclide has particular organs for which it pharmacologically concentrates. For example, I^{131} in the thyroid, Plutonium in the lung, bone and liver. Depending on dose and biological half-life the radionuclides are cancer risks to specific organs. Uranium as a heavy metal is also toxic to the kidneys. Plutonium's toxicity is due to its radioactivity and not that it is a heavy metal.

B. Non-Radiological Health Hazards

This section on chemical exposures gives for each chemical: a) a synopsis of its use at SRS, b) its acute and chronic symptoms during exposure, and c) long term (residual) effects. The first two areas identify workers who may have been overexposed if their job classification were known, and the significant symptoms that they may have had at the time of exposure. The final section gives medical effects that may be identified in retired workers through medical examination, as well as identifying problems where treatment could be of value. Most of this preliminary material is taken from a standard reference work (Proctor and Hughe's Chemical Hazards of the Workplace), and from John Hickey and Donna Cragle's Occupational Exposures of Workers at the Savannah River Site, 1952-1984. As we learn more about the specific needs of the SRS site, this information will be updated and refocused on site specific needs. As will be seen, exposures to these compounds give a number of persistent and/or late developing effects of great importance to the health of former workers.

It appears that personal monitoring at the SRS site was fully developed only after about 1990. In the absence of detailed personal exposure records, there is not much to be gained about giving quantitative details of the effects of exposure, so what is presented here is qualitative. This approach can be changed to match the extent that quantitative personal exposure data becomes available. Below are listed 17 hazards that have been identified as substances of concern in the Hickey and Cragle's investigation or substances listed in SRS's Tickler file and Medical record database (as E-codes). There are sixteen chemical hazards, one physical, which are presented in alphabetical order.

1. Asbestos

Exposure at SRS

At the time of the development of the SRS site, asbestos was widely used as a component of shingles, wallboard, pipe insulation, etc. Asbestos is found widely across the site, and although not being brought onto the Site at this time, it is a potential hazard to nearly all employees involved in renovation or shutdown of processes.

Acute Symptoms

Asbestos exposure has no acute symptoms, which is a major reason its latent effects were overlooked for such a long time, and that workers can be overexposed far over the recommended exposure limits without their knowledge.

Long Term (Residual) Effects of Exposure

By itself, asbestos exposure can cause mesothelioma, a universally fatal lung cancer. In conjunction with tobacco smoke, asbestos is a potent co-carcinogen for bronchiogenic carcinoma. High chronic exposures to asbestos cause a fibrosis of lung tissue (asbestosis) that also can be fatal. Asbestosis presents a characteristic roentgenic picture. Also seen in conjunction with asbestosis are restrictive pulmonary function, fine rales, finger clubbing, dyspnea, dry cough, and cyanosis.

2. Benzene

Exposure at SRS

The use of benzene at SRS not known; possibly separations.

Acute Symptoms

High concentrations of benzene – i.e., 20,000 ppm – cause convulsions and death in minutes. Exposures in the range of 3,000 ppm result in irritation to the eyes and respiratory tract. Still lower concentrations – 250 – 500 ppm – produce vertigo, headache, and nausea.

Long Term (Residual) Effects of Exposure

The most significant effect seen is aplasia and fatty degeneration of the bone marrow. This may progress to leukopenia, anemia, and finally a bone marrow necrosis termed aplastic anemia. Symptoms seen in individuals so affected include light-headedness, headache, loss of appetite, and abdominal discomfort. Also seen are weakness, blurring of vision, dyspnea, and a hemorrhagic tendencies (easy bruising, epistaxis, bleeding from the gums). Benzene has been found associated with leukemia in many epidemiology studies, primarily of the acute and myeloblastic type. Recently prolonged occupational exposures have shown an increase in non-Hodgkin's lymphoma.

3. Dioxane

Exposure at SRS

The use of dioxane at SRS is not known.

Acute Symptoms

Both inhalation and skin absorption are important routs of entry for dioxane. Dioxane is sufficiently toxic to have caused death in workers after little more than a month's heavy exposure. It causes irritation to eyes and mucous membranes. Autopsies of humans who died from overexposure to dioxane showed liver and kidney damage, and edema of the brain and lungs.

Long Term (Residual) Effects of Exposure

Liver and kidney damage, which may be ascertained from the appropriate function tests. Cancer and teratogenic effects are unproven in humans, although cancer has been found in laboratory animals treated with dioxane.

4. Hydrazine

Exposure at SRS

Hydrazine was used in separations. Exposure to hydrazine occurs through inhalation and skin absorption.

Acute Symptoms

Hydrazine is a severe skin and mucous membrane irritant, a convulsant, a hepatotoxin, an allergen, and a moderate hemolytic agent. In humans the vapor causes nose and throat irritation, dizziness and nausea, itching and burning of the eyes. The vapor can cause temporary blindness.

Long Term (Residual) Effects of Exposure

Although hydrazine produces cancer in animals; there is insufficient evidence to claim the same for human exposure. In a case of very high exposure, autopsy results showed fatty degeneration of the liver and nephritis.

5. Hydrofluoric Acid

Exposure at SRS

Hydrofluoric acid was used at SRS in separations processes, probably in heavy metal reduction.

Acute Symptoms

The normal exposure route for hydrogen fluoride is inhalation and (for its aqueous solution) dermal contact. For elemental fluorine, inhalation is the pathway of concern. Hydrogen fluoride as a gas is a severe respiratory irritant, and in solution it causes severe and painful burns of the skin and eyes. Acute inhalation can result – after an asymptomatic period of several hours to several days – in fever, cough, dyspnea, cyanosis, and pulmonary edema, which can be fatal.

Significant absorption may result in hypocalcemia and hypomagnesemia. Cardiac arrhythmias may ensue.

Long Term (Residual) Effects of Exposure

Chronic respiratory effects include hoarseness, coughing fits, and nosebleeds. Continuous overexposure may result in increased radiographic density of the bone and eventually crippling fluorosis (osteosclerosis due to fluoride deposition in the bone). The early signs are seen in bone density as found in x-rays of the lumbar spine and pelvis.

Skin contact with hydrogen fluoride solutions can cause marked tissue destruction. Because of the insidious nature of its penetration, a mild exposure can cause a serious burn; the result is necrosis of soft tissues, decalcification of bone, tendonitis, and tenosynovitis. Eye exposure to hydrogen fluoride solutions is very painful and can cause severe, permanent injury.

Renal failure is an unproved, but suspected effect.

6. Hydrogen Sulfide

Exposure at SRS

Deuterium production.

Acute Symptoms

Only important route of exposure is inhalation. 1000 ppm can cause coma after a single breath, and be rapidly fatal owing to respiratory paralysis. At lower levels, symptoms seen include neurological effects, e.g.: nervousness, headache, fatigue, weakness of extremities, spasms, vertigo, convulsions, agitation, and delirium. Symptoms of gastrointestinal disturbances, including nausea, abdominal cramps, vomiting, and severe diarrhea are also seen. Pulmonary edema is common after exposure to 250 ppm for prolonged periods of time. Exposure over 50 ppm for one hour can lead to acute conjunctivitis. Hydrogen sulfide has the strong odor of "rotten eggs", but because hydrogen sulfide deadens the sense of smell, odor recognition by workers is a poor method to evaluate its concentration.

Long Term (Residual) Effects of Exposure

Direct damage to cardiac muscle tissue has been suggested from electrocardiographic changes. Increased incidence of heart attack has also been reported (Carl Schultz, personal communication). Fatigue, headache, dizziness, and irritability are also thought to be effects of chronic exposure.

7. Lead

Exposure at SRS

Lead is an important shielding material.

Acute Symptoms

Occupational exposure is not likely to cause acute symptoms.

Long Term (Residual) Effects of Exposure

Lead causes a host of unpleasant effects, the most common of which is probably lead colic, which can be extremely painful. Other complaints often seen are: weakness, weight loss, lassitude, anemia, neuromotor dysfunction and motor weaknesses, i.e. the "wrist drop" and "foot drop" associated with chronic lead poisoning. Motor and sensory nerve conduction velocities may also be reduced. An increased death rate resulting from kidney failure has been reported. Lead accumulates in the body, especially in the bone, and an elevated blood lead level is indicative of exposure.

8. Mercury

Exposure at SRS

Mercury and mercuric nitrate were used in the H-Area and in tritium production.

Acute Symptoms

Inhalation of mercury vapor may produce a metal-fume-fever-like syndrome, including chills, nausea, general malaise, tightness in the chest, and respiratory symptoms. High concentrations cause corrosive bronchitis and interstitial pneumonitis.

Long Term (Residual) Effects of Exposure

Chronic exposure gives weakness, fatigue, anorexia, loss of weight, and gastrointestinal changes. At higher exposures a chronic mercurial tremor appears, starting with the fingers, eyelids, and lips; and perhaps becoming generalized throughout the body. Also seen are behavioral and personality changes, increased excitability, loss of memory, insomnia, and depression, and kidney damage. An electromyograph may determine the extent of nerve dysfunction.

9. Nickel

Exposure at SRS

Nickel was used at SRS in plating and target elements.

Acute Symptoms

Nickel metal and certain of its salts cause a dermatitis, "nickel itch", once the body has become sensitive to nickel.

Long Term (Residual) Effects of Exposure

Nickel and some of the compounds associated with nickel refining, e.g., nickel carbonyl, nickel oxide, and nickel sulfide, are associated with nasal cancer.

10. Nitric Acid; Oxides of Nitrogen

Exposure at SRS

Nitric acid was used in large quantities in uncladding and dissolution of fuel and targets; in fuel and target fabrication; and in resin regeneration and pH control. Nitrogen dioxide evolves in all but the latter usage.

Acute Symptoms

Nitric Acid

Nitric acid causes corrosion of the skin and other tissues on contact. The result is severe burns, skin stains (bright yellow to yellowish-brown) and penetrating ulcers.

Nitrogen Dioxide

The oxides of nitrogen produced from nitric acid lead to pneumonitis and pulmonary edema. Symptoms reported include dryness of the nose and throat, cough, chest pain, and dyspnea. The odor threshold for nitrogen dioxide is 0.12 ppm, below its TLV of 3 ppm. Workers who do not notice its odor during exposure are unlikely to be overexposed.

Long Term (Residual) Effects of Exposure

Nitric Acid

Contact by nitric acid with the skin or eyes can give scarring and vision problems. It is thought, but not certain, that chronic exposure may cause dental erosion

Nitrogen Dioxide

Pulmonary damage from nitric and nitrogen dioxide can lead to chronic obstructive pulmonary disease – the formation of fibrous tissue that can obliterate the bronchi and bronchioles. This damage may be determine by pulmonary function tests and by the radiographic pattern seen in such lungs.

11. Noise

Exposure at SRS

There has been a continuous program of noise monitoring and noise reduction throughout SRS, indicating that noise overexposure was of concern throughout the site for some time.

Acute Symptoms

Any area where workers must shout to be understood is likely to be an area where the ambient noise level is over 90 dBa, which is the level at which hearing protection is required. Ringing in the ears or a temporary threshold shift in hearing are also associated with excessive noise levels.

Long Term (Residual) Effects of Exposure

The 4,000 Hz notch in the audometric test can be used to identify occupational hearing loss. Overexposure to noise has been linked to a number of other effects, including high blood pressure; but the data for all but deafness is still controversial.

12. Oxalic Acid

Exposure at SRS

Oxalic acid was used in large quantities in separations and in reactor operations, and at the receiving basin for offsite fuels. Oxalic acid has a very low vapor pressure, limiting its exposure to situations where ingestion has occurred, or where its mist is present.

Acute Symptoms

There is little reported industrial exposure, although inflammation of the respiratory tract has been reported from exposure to hot vapors of the compound. Oxalic acid is poisonous – binding with ionized calcium in body fluids, causing shock, collapse, and convulsions – and as little as five grams of the ingested material has caused death.

Long Term (Residual) Effects of Exposure

Renal damage from the deposition of calcium oxalate may be determined through kidney function tests.

13. Perchloroethylene

Exposure at SRS

Perchloroethylene was used at SRS in cleaning fuel and target fabrication.

Acute Symptoms

Occupational exposure has caused central nervous system depression, including dizziness, light-headedness, "inebriation", slurred speech, headache, and difficulty in walking.

Long Term (Residual) Effects of Exposure

Perchloroethylene causes peripheral neuropathy, liver damage, and causes cancer in laboratory animals. Prolonged exposure has caused impaired memory, numbness of extremities, impaired vision. Liver function tests can determine the extent of the liver damage. Case control studies with exposed occupational personnel, e.g., laundry workers and dry cleaners, have reported various excesses of various cancers, but these studies still seem inconclusive. NIOSH recommends that perchloroethylene be treated as a potential human carcinogen.

14. Phosphoric acid

Exposure at SRS

Phosphoric acid was used for cleaning purposes in heavy water production, separations, and resin regeneration. Phosphoric acid has a negligible vapor pressure; routes of exposure are inhalation of phosphoric acid mist, or skin contact.

Acute Symptoms

Phosphoric acid is a mild irritant of the eyes, upper respiratory tract, and skin. Because of the irritating nature of its mist, exposure is likely to be highly limited. A 75% solution by weight will cause severe skin burns.

Long Term (Residual) Effects of Exposure

None are known.

15. Polychlorinated Biphenyls

Exposure at SRS

PCBs are liquids with very low vapor pressures; thus occupational exposure at SRS to PCBs is likely to be dermal.

Acute Symptoms

The outstanding finding after exposure to PCBs is chloracne. In the absence of chloracne, other effects are not expected.

Long Term (Residual) Effects of Exposure

PCBs accumulate in body tissues; an employee with a history of chloracne may want to be tested for PCB blood levels. Liver damage and increased rates of cancer are suspected results of PCB exposures; but from numerous epidemiological studies, such effects, if they do indeed exist, are very weak.

16. Sulfuric Acid

Exposure at SRS

Sulfuric acid was used at SRS in hydrogen sulfide manufacture, and in the power department. Because of the low vapor pressure of sulfuric acid, industrial exposure is limited to dermal contact and mist inhalation.

Acute Symptoms

The acid mist is highly irritating – and its very unpleasantness limits the contact that a worker will endure. Dermal contact produces chemical burns, which are long in healing.

Long Term (Residual) Effects of Exposure

Exposure to sulfuric acid mist can erode dentine and tooth enamel. Also seen are scars from dermal contact. Chronic exposure to acid mists in general – including sulfuric acid mist – are associated with increased rates of laryngeal cancer.

17. Tributyl Phosphate

Exposure at SRS

Tributyl phosphate was use as a solvent in F and H Areas of separation

Acute Symptoms

Tributyl phosphate is only moderately toxic, having an oral LD50 in rats of 3 g/kg. Workers exposed to its vapors have complained of headache, nausea, and irritation of the eyes, throat, and mucous membranes.

Long Term (Residual) Effects of Exposure

No long-term effects from occupational exposure to tributyl phosphate have been proven.

VIII. Medical Surveillance for Former SRS Production Workers

A. Need for medical surveillance and risk communication

The need for continued medical surveillance and risk communication would ordinarily be determined by some quantitative estimate of the amount of ill health or potential for development of ill health that is embedded in the former worker population because of some effect of the work at the SRS. A quantitative prediction of adverse health effects from work related exposure would depend on an accurate hazardous exposure record. We have found that SRS exposure records which are linked to individual workers are available only related to the exposure to ionizing radiation and a few non-radiological hazards (mainly during asbestos removal). Exposures to chemicals and other hazards can only be estimated by studying work records from which some indication of work location and duration of exposure can be estimated.

During interviews with self-selected groups of former workers, it became apparent that there was a great deal of variation in the perception of individuals about the potential for current ill health which might be related to exposure during the working period at the SRS. There was also a frequently expressed need for a higher level of understanding about the potential for work related adverse health effects as well as the possibility of mitigating those effects.

Medical surveillance is warranted for production workers due to the lack of personal exposure sampling and the likelihood of worker exposure to a variety of hazardous substances. Further, investigators involved with the DOE Medical Surveillance of Construction Workers: Part I (Center to Protect Workers Rights, 1998) project found documents that showed releases of hazardous agents in the workplace. These documents are listed in Appendix 11. Also, the ORPS database reviewed also indicated that releases of contaminants occurred in the work environment (see section V.C.b.2.c).

To further support the need for medical surveillance, there is evidence to indicate that occupational exposures at SRS have adversely impacted workers health. The MUSC/USC study team very recently received from SRS (6/22/98) the requested medical data file containing the basic data on all individuals employed by the prime contractors (DuPont and Westinghouse). This file of 25,580 individuals contains for each former employee: name, SSN, employee type (retired, terminated operations worker, deceased worker), sex, race, hire date, termination date, deceased date, date of last exam, job title, ICD code, exposure code, x-ray code and x-ray date. Although we have not had time for a detailed analysis of this file some preliminary calculations have been carried out. Table 5 shows that we have a list of names and addresses of a total of 25,580 former workers of whom 23,496 (25,580-2084) are potential candidates for medical surveillance.

Table 5

Former Workers from 1962-1998 at SRS

Type	Number
Former Operations Worker	19,677
Retiree	3,085
Deceased	2,084
Unspecified	734
Total Former Workers	25,580

Because of the paucity of information on individual workers exposure to hazardous substances, a reasonable approach to establish a medical surveillance protocol would be to use the hazards of concern identified by the health, safety, and medical professionals of SRS. These hazards were identified in the database for Tickler files and Medical records (as E-codes). These are files identify former workers who have potential exposure to specific chemical hazards. However, these records list only relatively small populations in comparison to the total population of former workers. SRS personnel also contend that the E codes are not complete and should not be used to indicate all workers exposed to a particular contaminant. E code (hazard exposure) files have been maintained for the following lists of exposures:

Table 6

Hazardous Substances Codes (E-codes): Internal SRS use only.

E01*	Transuranium	E06	Asbestos Worker
E01.1	Transuranium Registry	E07	Dioxane Worker
E02	Hydrazine	E08	PCB Exposure (polychlorobiphenyl)
E03	Perchlorethylene	E09	H2S Exposure (hydrogen sulfide gas)
E04	Laser Worker	E10	Tritium Exposure
E05	Neutron Worker		

* Includes californium, uranium, DU, Plutonium, ASLI

Subsequent to 1989, lists of exposed workers were maintained in "Tickler" Files of the medical data set. The "Tickler Files" included individuals with potential exposure to the hazards listed below. Because of the small number of individuals included in the E-Code Files and the "Tickler" Files, we believe it is unlikely that these lists are inclusive of all individuals who have some potential for hazardous exposure even though the list of hazardous agents is probably a reasonable representation of important hazards which existed in the work environment of the SRS.

Table 7

Hazard	Recorded Population (Tickler Files)
Asbestos	454
Benzene	8
Enhanced Fitness for Duty	3
DOT Drivers	55
Laser Worker	8
Firefighters	16
Hazardous Waste Workers	77
Hearing Conservation Program	508
Blood Lead Surveillance	0
PSAP (Personnel Security Assurance Program)	48
Liquid Effluent Treatment Facility	3

We did not consider the following items on the Tickler File a concern for surveillance because they were not a specific hazard or there were too few individuals listed in the category: Enhanced Fitness for Duty, DOT Drivers, Laser Worker (also in E codes), Firefighters, Hazardous Waste Workers, Surveillance/Qualification Program, Blood Lead Surveillance, Personal Security Assurance Program, Liquid Effluent Treatment Facility. Benzene was not included as a chemical of concern for surveillance, because benzene exposure was not typical at SRS. Benzene was included in the Tickler data file because a few workers transferred from a DuPont plant in Louisiana where benzene was used in production. SRS continued to provide these workers health screenings (Kahal, 1998). We included beryllium and trichloroethylene as chemicals of concern. The DOE's interest in beryllium and beryllium's presence on the SRS site warrant its inclusion. Trichloroethylene was used in earlier years as a solvent (prior to perchloroethylene). While constructing the registry of former workers shown in Table 5, a few specific ICD codes of diseases of particular interest were collected. Table 8 presents this data from the SRS medical department's records.

Table 8

ICD Disease Codes in the SRS Medical Department's Records

Code	Disease	Cases
163	Lung cancer	16
188	Bladder cancer	114
238	Neoplasm of Uncertain Behavior	263
389	Hearing loss	8221
501	Asbestosis	39
506	Respiratory due to chemicals	20
692	Contact dermatitis	6005

In this file we see that a large number of workers (8221) are identified with a hearing loss as well as a large group (6005) reporting contact dermatitis.

Also x-ray reports were reviewed using ACR (American College of Radiology) codes. There were a total of 3821 records with at least one of the codes noted. Of particular interest is code 60-520 that corresponds to abnormal pulmonary residual effects from toxic inhalation of chemicals or fumes. This category included 1430 individuals. These radiographs should be reviewed to verify the clinical classification of the x-ray diagnosis.

The medical system at SRS had several exposure categories in which workers could be placed for medical monitoring purposes. The exposure categories were called e-codes and are described elsewhere. In Table 9 we see the numbers of entries by e-code and former employee status. From this data we then know for example that at least 1183 retirees had presumed exposure to asbestos.

Table 9

Identified exposure groups (e-codes)

Exposure Group	Retiree	Terminated	Deceased	Total
Transuranium	203	19	56	393
Hydrazine	110	4	23	137
Perchloroethylene	80	10	26	116
Laser Worker	40	9	5	54
Neutron Worker	5	1	2	8
Asbestos Worker	1183	133	375	1691
Dioxane Worker	8	0	2	10
PCB exposure	13	0	6	19
Hydrogen sulfide	1532	444	683	2659
Tritium	19	5	6	30
Total	3193	625	1184	5002

To develop some quantitative estimate of risk (the risk of adverse health effects from work-related exposures), industrial hygiene sampling records were reviewed for the site. These are summarized in Table 3. Unfortunately, these are only area measurement records and provide no information on which to base quantitative estimates of individual health risk. These records do provide some evidence of the presence of specific hazardous materials but certainly do not prove that any individual was in contact with the hazard and if some contact occurred, there is no information about duration or concentration. In Table 10 is presented the hazards of concern in future health screenings. Many additional chemicals described in Section VIIB were present but we have no evidence of worker exposure.

Table 10

Hazardous Substances of Concern and Known Chronic Health Effects

Asbestos	Mesothelioma, bronchiogenic carcinoma, asbestosis, restrictive pulmonary function, fine rales, finger clubbing, dyspnea, dry cough, and cyanosis
Beryllium**	Berylliosis, IARC classifies as human carcinogen (lung)
Dioxane	Liver and kidney damage; animal carcinogen
Hydrazine	Liver and kidney damage; animal carcinogen
Hydrogen Sulfide	Cardiac muscle tissue damage, possibly increases heart attack risks, fatigue, headache, dizziness, and irritability
Ionizing Radiation	Most cancers
Internal Radiation	
Americium	Liver, bone cancer
Plutonium	Lung, liver, bone cancer
Tritium*	Most cancers
Noise	Hearing loss, possibly increases blood pressure
Perchloroethylene	Peripheral neuropathy, liver damage, cancer in animals, impaired memory, potential human carcinogen (NIOSH)
Polychlorinated Biphenyls	Chloracne, liver damage and cancer are also suspected effects
Transuranium	Lung, liver, bone cancer, kidney disease
Trichloroethylene	Possible central nervous system changes, liver and kidney damage, hematological effects (including leukemia)

* It is uncertain if bioassays for tritium were conducted; its inclusion on this may change if future information indicates change is warranted.

** We found no documented exposures to beryllium; however, beryllium was listed as a hazardous substance onsite (in $DPSOP_{158}$). Because of DOE's concern for occupational exposures to this substance, we have included it in our list.

We note that other toxic chemicals were present (see Table 2 and Section VIIB) but so far have no evidence of worker exposure.

B. Estimation of Population at Risk

Because of the small number of individuals included in the E Code Files and the Tickler Files, we believe it is unlikely that these lists are inclusive of all individuals who have some potential for hazardous exposure even though the list of hazardous agents is probably a reasonable representation of hazards which existed in the work environment of the SRS. Therefore, we relied on the available data to generate upper and lower bounds for the number of workers potentially exposed to the hazards of concern for medical surveillance.

We used the HPAREA file in Cragle's data to estimate distribution of former workers assigned to specific health physic departments within the SRS complex. The HPAREA is the only data we have obtained to date that contains a code that links a worker to a location at the SRS site. However, this code is limited in that a health physics department assigned to a worker does not necessarily indicate where the worker conducted his/her daily job duties; rather, it indicates an administrative area associated with the department of a worker. Among the 29,739 persons listed in the file, 17,632 persons were listed as construction workers (code number 040), visitors (053-055), or people other than those of interest to our study. There were 279 persons with missing health physics department code, and 11,828 individuals with a health physics department code between 100 and 975. An estimate of the distribution of workers within health physics department was based on the data from these 11,828 former workers. This distribution assumes that the distribution of this group of former workers from 1952 to 1989 approximates the distribution of the entire population of former production workers within health physic departments.

On 6/22/98 we received a database of SRS medical records that contained data on 25,580 individuals. Due to the lack of time, only limited analysis on this data was possible. However, we present an analysis on the Cragle data that shows the age distribution for her study population. As the population we are interested in makes up a large portion of the Cragle data, we used her data to estimate the age distribution of our population. These results are presented in Table 11.

Table 11

Age distribution of 12,639 former worker in 1989 (Cragle data)

Age	Men	Women
<25	2554	1244
25-34	3746	1048
35-44	1430	221
45-54	521	103
55-64	1412	129
65+	207	20
Total	9870	2769

The estimated percentage of former SRS production workers by health physics department is as follows:

100 area (Reactors):	7.7%
200 area (Separations):	13.0%
300 area (Fuel and Target):	3.5%
400 area (Heavy Water):	2.5%
500 area (Health Protection and Labs):	9.3%
600 area (Works Engineering):	13.7%
700 area (Service and Administration):	7.2%
800 area (Security, Personnel, Medical):	6.2%

Records from industrial hygiene (Table 3), information from the Hickey and Cragle report (1985) (Appendix 1) as well as the RAC (1995) reports were used to link HP codes with locations where hazards were used. Multiplying the proportion of former workers who worked in specific HP departments (estimated from Cragle's data) times the number of total former workers (23,496) gave an estimate of the possible number of people exposed to a particular non-radiological hazard. For radiation exposures (internal and external), data from SRS radiation monitoring records were used to estimate the proportion of workers with cumulative exposures greater than 20 rem. This proportion was then multiplied by the total number of former workers (23,496). The results of these calculations are shown below in Table 12.

Table 12
Location of Hazards and Estimated Number of Former Workers at Risk for Exposure to Hazards of Concern

Hazard	Location(s)	Recorded Population*	Estimated Number Potentially Exposed
Asbestos	All	1,770[1]	4,000[2]
Beryllium**	Unknown	0[2]	100[2]
Dioxane	300 Area	8[1]	822[3]
Hydrazine	200 Area	114 [1]	3,054[3]
Hydrogen Sulfide	400 Area	1,976[1]	4,000[2]
Ionizing Radiation (external)	100, 200, 300, & Waste Areas	340[5]	574[6]
Internal Radiation	Don't Know	150[7]	---
Noise	Power Houses***	8,221[8]	10,000[2]
Perchloroethylene	100, 300, 700 Areas	90 [1]	4,323[3,4]
Polychlorinated Biphenyls	Unknown	13 [1]	---
Trichloroethylene	300 Area	---	822 [9]

1 Based on E-codes from SRS medical records and tickler files.

2 Professional judgment of researchers

3 Use of industrial hygiene records, health physics (HP) codes, proportion of workers who worked in HP area in Cragle's data multiplied by the number of terminated employees (23,496)

4 Use of industrial hygiene records, health physics (HP) codes, proportion of workers who worked in HP area in Cragle's data multiplied by the number of former employees (23,496)

5 Use of Dr. Ken Crase's SRS radiation monitoring results (page 19) of distribution of 39,673 proportion of badged individuals who had cumulative exposures ≥ 20 rem, multiplied by the number of terminated employees (23,496). If ≥ 10 rem was used as the cutoff, the number would be 825 people.

5 Based on all individuals in SRS radiation monitoring results (page 19) who had cumulative exposures ≥ 20 rem. If ≥ 10 rem used as cutoff, 1,398 people would be the upper bound.

6 The lower bound is considered a reasonable estimate derived from Dr. Ken Crase's SRS radiation monitoring data (page 22) where 5 rem internal dose is used as a cutoff. Five rem was used here because the data are whole body dose, and particular radionuclides may concentrate in localized body organs. This type of concentration may make an actual exposure to an organ 10 times greater. The lower bound of 150 is based upon a total of 1,039 badged individuals of which 173 measured ≥ 5 rem. Lack of data prevented estimating an upper bound.

8 Based on ICD codes analysis of SRS medical records (Table 8).

9 Use of Radiation Assessment Corporation's report (1995), health physics (HP) codes, proportion of workers who worked in HP area in Cragle's data multiplied by the number of terminated employees (23,496)

* Based on E-codes and Tickler file numbers.

**We found no documented exposures to beryllium; however, beryllium was listed as a hazardous substance onsite (in $DPSOP_{158}$). Because of DOE's concern for occupational exposures to this substance, we have included it in our list.

*** From the ICD code report of 8,221 workers with hearing problems there are likely other areas of noise besides the Power Houses.

C. Feasibility of Contacting former SRS Workers

Approach

Index workers will be identified from the list of former SRS workers. While all variables on the index files will be used in the location process, name, date of birth, address, phone number, race, gender and type of worker will be considered essential items for the record. As these original work records were created over time since the facility first began operation in the 1950's, much of the information regarding location would be expected to be out of date. Thus, these lists will function as a starting point for the location process. The process will consist of "detective work" piecing together clues gathered from multiple sources. This task will be plagued with false starts, dead ends and blind alleys. Nonetheless, the approach will be systematic designed after the methodology of other epidemiologic studies such as the agent orange and Vietnam veterans studies, which use similar location methods.

1. Worker Lists - The first location attempt will utilize the information from SRS databases (e.g., Medical Records). Contact will be attempted by telephone and mail using the available information. Clearly, successful contacts will utilize the opportunity to update the information in the records used for identifying the workers. Components of the contact file:

   List of information:
   Full Name
   Social Security Number
   Address
   Termination category

   After attempts to locate the workers using the SRS information, the process will continue with the other sources.

2. Assessment of vital status using the National Death Index (NDI) - The NDI will be used to identify the workers who have died. The NDI involves the matching of the worker rosters with the national death files. A list of probable matches based on name, social security numbers, date of birth, race and gender will be provided as part of the process. The NDI will provide the probability of a match and the death certificate number and state of death. Since the match is not complete after this step, the death certificates will be requested from the state of death. Information from the death certificate will be used to determine if this certificate does indeed correspond to the individual on the roster list. As well, information on the death certificate, such as cause of death, usual physician, place of death and informant name might be useful in the study.

3. Internal Revenue Service - The Public Law 95-210 allows the IRS to disclose mailing addresses of taxpayers to the National Institute of Occupational Safety and Health

(NIOSH) for investigations. A collaborative arrangement will be made with NIOSH to complete this aspect of the study.

4. Telephone Company Directories - The telephone directories from across the country will be used to match names. These directories are maintained on the computers of the Survey Research Facility (SRF) at MUSC.

5. US Postal Service - All mail attempts will utilize an address correction procedure which will allow the Postal Service to correct the address if the information is available.

6. Department of Transportation - The Motor Vehicle Departments in SC and GA will be approached regarding driver's license and motor vehicle registration for potential matches. Social Security Numbers, names, date of birth, and race are available.

7. Voter Registration - Voter registration in SC and GA will be approached to solicit potential matches with worker's list. Social security numbers and names will be used for the match.

8. Credit Bureaus - Credit bureaus will be contacted and compensated for completing a credit check to identify locating information.

9. Neighbors and Co-workers - Former neighbors and co-workers will be contacted and interviewed regarding the current location of the worker. Neighbors will be identified using city directories from the area. Co-workers will be identified from located workers on the worker's lists.

10. Investigator Firms - As a final attempt, investigator firms such as Equifax, will be employed to locate the workers. Such firms will be compensated for their services. Since this is a costly activity, all efforts will be used to assure this is the final activity in the location process.

After location, living workers will be contacted by mail and telephone, and solicited for participation in a telephone interview regarding their work history and health. The interviews will be conducted using a Computer Assisted Telephone Interview (CATI) methodology.

PILOT STUDY

Two searches were completed during the pilot phase of the location process. Rosters were provided to the SRF and the electronic phone books were used to identify telephone numbers based on name and address.

1. Workers Seen In Clinic – A roster of 88 names and last known addresses of former and current workers seen at the clinic were provided to SRF for phone matches. Using

the electronic phone book and matching process of name and address, 63 (72%) were successfully identified with a working telephone number. During a 4-day period, these numbers were called and interviews were completed on 41 of the former workers. The former workers responded to questions regarding perceptions about their health and potential exposures. Cooperation was detected from this contact.

In summary, this assessment demonstrated the ability to successfully locate a significant number of workers with the first process (use of electronic phone book) and a reasonable level of cooperation from the workers to participate in a surveillance program.

2. Location From Worker Rosters – The second phase of the pilot study involved the locating of a sample of the total workers. A random sample of 292 of the 20,000 workers was selected. Name, social security number, address, race, sex and date of birth were provided to SRF. The electronic phone books were searched for six hours matching names and addresses with the following results:

Number Provided	Telephone Matched
Retirees 57	35 (61.4%)
Terminated Operator Contractors 235	56 (24.0%)
Total: 292	**91 (31.2%)**

The initial search process was clearly more successful with the retirees, a group most likely to have remained in a single location. In contrast, the workers designated as operating contractor termination were most likely workers who had re-located. The implementation of additional search modes, such as national searches, etc should substantially increase the success ratios. Likewise, the National Death Index search should be implemented after the various modes have been completed since a significant number may be deceased.

In summary, the two phases of the pilot efforts have determined that a significant number of the workers can be identified from available records. This observation suggests that implementation of additional search modes will increase the yield, and that once contacted, the workers appear cooperative and willing to participate in a surveillance program.

D. Educational needs and health concerns of former workers

Our contact with subsets of the former worker population shows a great deal of concern about any current and future health risk caused by work-related exposures. These former workers also indicated distrust of hazardous exposure records except for the records recording exposure to ionizing radiation. Because of this concern and the degree of uncertainty about a wide range of potentially hazardous exposures, a considerable amount of education is needed to obtain concurrence between the former workers' perception of risk and realistic risk estimates based on work-related hazard information obtained from SRS records. Actually, this need for a higher level of technical education about the probability of adverse health effects related to work at the SRS is the strongest argument for using a general health risk appraisal as the initial approach to medical surveillance. Experience with health risk appraisal instruments has shown the educational effect of these individual reviews of current health state. The individual health risk appraisal also leads to a contact period during which an individual occupational history can be obtained and this will allow for additional education of the individual about the potential association of adverse health effects with specific work related hazard exposure. From our contact with former workers, it is clear that this is a knowledgeable and interested group who would derive considerable benefit from additional hazard / health education. It is likely that they would find this additional education reassuring and would develop an even more positive attitude toward the Department.

E. Approach to medical surveillance

Because of the uncertainty about individual exposure to hazardous substances at the SRS, almost all former workers should be offered the opportunity for an initial health risk appraisal which has been modified specifically for known hazards at the SRS. Reasonable exclusion of former workers could include workers who only worked in purely administrative positions and whose administrative activities took place entirely within areas of the site in which there was no known hazard. It may also be acceptable to exclude those workers who have less than a three year working history at the SRS but, for the purposes of this project, it seems more reasonable to avoid any "time-of-work" exclusion. The number of workers eliminated by this type of exclusion would be relatively small and it is possible that significant short-term exposures could be missed. Since the cost of the initial health risk appraisal is relatively low, it is likely that the educational effect would justify the cost even for individuals whose working period at the SRS was relatively short.

Based on the results of the health risk appraisal, additional specific medical testing should be directed to problems identified by the health risk appraisal which can reasonably be associated with the work experience at the SRS. The specific tests and examinations required for this screening are likely to be related to exposures to hazards listed in the E-Code and "Tickler" files. Those work-related hazards, the target organs and the recommended health surveillance procedures are described in the chart below.

Medical Screening

HAZARD	TARGET ORGAN(S)	HEALTH OUTCOMES	RECOMMENDED TESTS AND SERVICES FOR SCREENING
Asbestos	 Lung Intestinal Kidney Heart	 Chronic bronchitis Bronchogenic Carcinoma Mesothelioma Asbestosis Non-malignant pleural reactions Colon Cancer Renal Cancer Ischemic Cardiac Disease	• Work exposure history • Medical history – past and present • Physical exam • Chest radiograph: interpreted by International Labor Office criteria • Spirometry • Fecal Occult Blood
Beryllium	 Lung Skin Heart	Sensitization Chronic Beryllium Disease Berylliosis, Lung Cancer Ulceration, Granulomas Ischemic Cardiac Disease	• Work exposure history • Medical history – past and present • Physical exam skin test • Blood or BAL* lymphocyte transformation / proliferation test (repeat if positive) • Blood/urine trace metals • Chest radiograph • Spirometry
Hydrazine	 Kidney, Urinary Tract Lung Liver Eyes Skin CNS	Weight loss, weakness, vomiting, excited behavior, convulsions. Bronchitis, pulmonary edema Fatty degeneration of the liver, nephritis Burns, temporary blindness Burns, contact dermatitis	• Work exposure history • Medical history • Physical exam • Blood chemistry • Urinanalysis • Spirometry • Chest radiograph • Liver function tests
Hydrogen Sulfide	 CNS	 Neurological abnormalities	• Work exposure history • Medical history • Physical exam • Blood chemistry • Neurological exam

	Lungs Eyes	Bronchitis, airway hyper-responsiveness, decreased function Conjunctivitis, corneal ulceration	• Chest radiograph • Spirometry • Vision test
Noise	Auditory system	Noise-induced hearing loss	Work exposure history Medical history Audiometry Impairment rating (if appropriate)
Perchloroethylene/ Trichloroethylene 	 Esophagus Lymphatics Cardiovas-cular CNS Reproduc-tive system	 Esophageal cancer Lymphoma (suspected CA site) Various neuropathies, neurobehavioral impairments Abortions, sperm quality	Work exposure history Medical history Physical exam Blood chemistry Barium swallow

The number of needed medical examinations and tests continues to be uncertain because of the lack of reliable, individual, hazard exposure information. The combination of the worker populations listed in the E-Code and "Tickler" files establishes a lower bound on the potentially exposed population for hazards of greatest concern. A qualitative evaluation of the exposure records which are available and a review of the historical activities of the SRS leads to an estimate of population size which establishes a fairly unreliable upper bound on the populations which will need health surveillance activities. A specific cost estimate for the most probable population size for health surveillance and medical treatment activities will be made in the Phase II proposal. The list given in Table 12 indicates the possible population size for each exposure of serious concern and also shows the level of uncertainty about the size of that population.

Exposure to ionizing radiation has been carefully measured since the beginning of radiation related activities at the SRS. The exposure can be connected to individuals and these data are considered to be reliable enough to use in determining risk. Aggregate radiation exposure is described in section V of this report. With the exception of a small group of individuals with significant internal deposition of radioactive material, the radiation exposure to individuals does not increase the risk of delayed somatic effects to a level that can be confidently determined to be different from the background occurrence.

To maintain some health surveillance equity and to reassure the former worker population of the Department's concern for future health problems, it would be reasonable to maintain general health surveillance of the population of workers who exceeded 20 rem of cumulative exposure during their working period at the SRS. Although it is not expected that these individuals will show a predictable increase in specific illnesses, there will be earlier detection of some neoplastic disease and the general health surveillance activities will promote increased education and understanding in this occupationally exposed population.

The question of health effects for the population with significant internal deposition of radioactivity is more complicated. Since internal dosimetry is much less certain, and there is likely to be considerable local variation in dose, it may be useful to do additional studies which might lead to a more accurate prediction of future health problems. Biomarker techniques may provide useful, predictive information. A proposal for the cost-effective use of these biomarker approaches will be made in a Phase II proposal.

During interviews with self-selected groups of former workers, it became apparent that there was a great deal of variation in the perception of individuals about the potential for current ill health which might be related to exposure during the working period at the SRS. There was also a frequently expressed need for a higher level of understanding about the potential for work-related adverse health effects as well as the possibility of mitigating those effects.

Because of the uncertainty about the size of the populations exposed to various hazards as well as the frequently expressed need for additional health related information, we believe it is necessary to offer a general health assessment to the entire former worker population. A customized **health risk appraisal** would be the most effective way to accomplish this objective.

We have identified about 23,000 former workers from SRS medical records. It is apparent that a large percentage of the former worker population continues to reside in the Aiken / Augusta area. Similarly to the construction workers population, it is likely that 80% of the former worker population lives within 80 miles of the SRS. A retiree's association exists which has address records approximately 1,400 members. Another loosely organized group of former workers meets regularly (monthly) in the city of Aiken and they can be easily contacted.

The former workers who participated in the telephone interview pilot project, as well as the self-selected group who met at the USC-Aiken campus in response to a newspaper advertisement, expressed a high level of interest in participating in any on-going health study. Many of those individuals expressed disappointment in the discontinuation of retiree physicals which were previously available at the SRS. Because of our experience in contacting small subsets of the former worker population as well as the expressed intensity of interest in health related matters, we estimate that 35% (or about 8,200) of the former worker population will participate in a health assessment if it is offered.

IX. Conclusions

To justify establishing a medical surveillance program for former production workers at SRS it is necessary to establish a need for such a program. We found evidence that toxic agents were present and that workers were exposed to some of these harmful agents while working at the SRS. There are a variety of chemical hazards at the site. We were able to make the determination about which hazards employees were be mostly likely to be exposed. Because of the uncertainty in a worker's job activities and uncertainty in the industrial hygiene monitoring data, we could only estimate ranges of numbers of workers potentially exposed to these agents. There are a number of indicators from medical records that points to possible exposures to employees. Examples include the approximately 8,000 employees identified with contact dermatitis and the 1400 individuals with radiographs indicating pulmonary residual effects from toxic chemicals. Therefore, what we have is knowledge of the toxic chemicals that employees were potentially exposed and evidence that there have been exposures and which exposures can produce important medical outcomes. What we do not have is the full linkage between the individual workers and particular exposures that the worker may have experienced. We have available the identification of approximately 23,000 former production workers and have shown that we will be able to locate a substantial proportion. We further estimate that about one third of these employees or roughly 8,000 would be interested in participating in some type of medical surveillance program. What we propose is to survey the former employees and provide a general health risk appraisal. For those that we determine to have had particular exposures we will develop a customized health risk appraisal for the worker.

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Appendix 1

Chemicals Identified by Production Area and Use as Being of Concern for Employee Exposure in Hickey and Cragle's (1985) Report

100 Area – Reactors

(In general, Hickey and Cragle reported chemicals were not a major hazard in reactor area)

nitric acid (pH control of D2O),
oxalic acid (decontamination and cleaning)
tritium (produced from irradiated D2O in cooling water)

200 Area – Separations

F-Area :

ruthenium tetroxide (dissolving byproduct (dust))
sodium hydroxide (decladding fuel elements)
sodium nitrate (declading fuel elements)
uranium oxide (dust, denitration, F area)

H-Area :

ammonia (decladding products)
manganous nitrate (clarifying fuel elements)
mercuric nitrate (dissolving fuel elements)
nitric acid (dissolving fuel, extraction of U and Pu, dissolving Pu/Np targets)
oxalic acid (precipitation of Pu and Np in target processing)
potassium permanganate (dissolving fuel elements)

Both F- and- H-Areas :

aluminum nitrate (extraction of U and Pu)
hydroxylamine sulfate (extraction of U and Pu)
iron sulfamate (extraction of U and Pu)
kerosene, m-dodecane, n-dodecane, dodecanol (extraction of U and Pu)
nitrogen oxides (emitted during dissolving, denitration)
silver nitrate (removing iodine from waste gas from dissolvers)
sodium carbonate (fuel dissolving, extraction of U and Pu, solvent decontamination)
sodium hydroxide (separations waste treatment; pH adjustment)
sodium nitrite (extraction of U and Pu)
tributyl phosphate (extraction of U and Pu)
plutonium fluoride (dust, processing Pu)
plutonium oxide (dust, processing Pu)

Appendix 1 (continued)

Chemicals Identified by Production Area and Use as Being of Concern for Employee Exposure in Hickey and Cragle's (1985) Report

200 Area – Separations

<u>Other Chemicals that may be of Concern :</u>

AHIB (possibly used in drum or cask cleaning)
ammonium hydroxide
ammonium oxalate
fluorine gas (possibly used in converting Pu to PuF3)
hydrazine mononitrate (possible carcinogen)
hydrofluoric acid (possibly used in converting Pu to PuF3)
liquid mercury
phosphoric acid (possibly used in drum or cask cleaning)
potassium fluoride (possibly used in drum or cask cleaning)
sodium bisulfate (possibly used in drum or cask cleaning)
sodium dichromate (human carcinogen)
sodium fluoride (possibly used in converting Pu to PuF3)
special material I (possibly used in converting Pu to PuF3)

<u>Chemicals of Most Concern in Separations</u> :

kerosene
nitric acid
sodium hydroxide
tributyl phosphate

Tritium Production : use for all chemicals other than lithium is unknown

EPON
gadolinium nitrate
lithium, lithium-aluminum, and other lithium compounds (irradiated for tritium production; other uses unknown)
metallic mercury
sodium borate
special materials "S" and "C"
tritium
various ion exchange resins

Appendix 1 (continued)

Chemicals Identified by Production Area and Use as Being of Concern for Employee Exposure in Hickey and Cragle's (1985) Report (continued)

300 Area – Target/Fuel Fabrication

lithium (fabrication of targets)
nickel (electroplating fuel and target elements)
nitric acid (cleaning fuel and target elements)
nitrogen oxides (gas emissions from fuel and target fabrication)
perchloroethylene (PCE) hot (cleaning fuel and target elements)
sodium hydroxide (cleaning fuel and target elements; waste recovery)
uranium dust (manufacturer of fuel cores)
UO_2 (recovered from U-target wastes)

400 Area : Heavy Water Production

ammonium (coolant in D2O rework operations) hydrogen sulfide (produced on-site; used in D2O production) iron sulfide (corrosion control chemical in H2S production)
phosphoric acid (used in drum cleaning)
K2CO3 (electrolyte in D2O concentration)
solvents (unspecified) (used in drum cleaning)
sodium hydrosulfide (feed chemical in H2S production)
sulfuric acid (feed chemical in H2S production)
sulfur oxides (potential emissions as byproduct of H2S)
trisodium phosphate (used in drum cleaning),
tritium (contaminant in D2O return from reactors for repurification)

SAVANNAH RIVER LABORATORY --

No routine exposure is presumed in the lab except for waste handlers, potentially exposed to the following: nitric acid, sodium hydroxide

Receiving Basin for Offsite Fuels (RBOF) and Resin Regeneration Facility (RRF).

RBOF

oxalic acid (filter cleaning)
sodium hydroxide (filter cleaning)

RRF

nitric acid (resin regeneration)
oxalic acid (filter cleaning)
phosphoric acid (target cleaning)
sodium dichromate (target cleaning)
sodium hydroxide (resin regeneration)

Appendix 1 (continued)

Chemicals Identified by Production Area and Use as Being of Concern for Employee Exposure in Hickey and Cragle's (1985) Report (continued)

Raw Materials Department—uses of chemicals are unknown

aluminum flouride
boric acid
butyl stearate
"filterbestos"
hydrogen peroxide
lead
lithium fluoride
methanol
nickel chloride
nickel sulfate
oils and lubricants
potassium fluoride
sodium carbonate
trichloroethane

Electric Plants

butyl stearate
chlorine (gas)
coal dust
diesel fuels
sulfur oxides

Appendix 2

Industrial Hygiene Sampling Conducted by Facility

Facility Number	Chemical
100 – Reactors	
105c	oil mist
	oxalic acid
105k	coal dust
	mineral spirits
1051	mineral spirits
105p	trichloroethane
	perchloroethylene
184k	coal dust
184p	coal dust
200 – Separations/Tritium	
F-b line	asbestos
H-area	4,4 methyldiniline
211f	mercury
221f	boric acid
	mercury
	mercurous nitrate
	methylene chloride
	nitric acid
	oil mist
	oxalic acid
	oxides of nitrogen
	styrene
	uranium
	uranium oxide
	welding fumes
221h	mercury
	neptunium
	nitric acid
	plutonium
	tributyl phosphate
	1,1,1-trichlorethane
222f	oxalic acid
	potassium permanganate
	sodium nitrate
223f	hydrazine mononitrate
232	freon tf (1,1,2 trichloro-1,2,2 tri-fluoroethane)
	paint vapors
	refractory ceramic fibers
234h	refractory ceramic fibers in packing operations
	paint vapors
241h	heat stress
247f	refractory ceramic fibers
284f	carbon monoxide
	coal dust
284h	carbon dioxide
	coal dust

Appendix 2 (continued)

Industrial Hygiene Sampling Conducted by Facility

Facility Number	Chemical
300 - Target/Fuel	
313m	acid mist
	aluminum oxide
	freon
	inorganic acid
	methylene chloride
	nickel
	nickel sulfate
	nitric acid
	nuisance dust
	oil mist
	oxides of nitrogen
	sodium hydroxide
	total dust
	1,1,1-trichloroethane
320m	lithium and aluminum
	nitric acid
	refractory ceramic fibers in casting area
	sodium hydroxide
	1,1,1-trichlorethane
321m	dioxane
	freon 113
	lead
	methyl chloroform
	nitric acid
	sodium hydroxide
322m	total particulate
400 - Heavy Water	
484d	coal dust
	crystalline quartz
	heat stress
	1,1,1-trichloroethane
600 –	
643g	respirable crystalline quartz
672-t	benzene
	phenol
675t	chromium
677t	sodium hydroxide
681-1g	air monitoring and urinalysis for mercury

Appendix 2 (continued)

Industrial Hygiene Sampling Conducted by Facility

Facility Number	Chemical
700 –Administration/Laboratories	
703a	perchlorethylene
	petroleum naptha
704-2z	fiber glass
710u	oxalic acid
710g	oxalic acid
717a	carbon monoxide
717f	metal fumes
	lead
717d	kerosene
717f	oil mist
	refractory ceramic fibers
	welding fumes
719a	acetic acid
722f	plutonium release 1/88
	total dust
723f	heat stress
729f	di (2-ethylhexyl phthalate)
	total particulate
771d	kerosene
	isopropyl acetate
772f	ketone
	methylethyl
	styrene
	xylene
773a	n-butyl acetate
	coal tar
	methylene bisphenyl isocyanate
	toluene-2,4-diiosocyanate
	xylene
Central Shops	
8303z (machine shop)	oil mist
8312	ammonia
	wood dust
8324 (insulation shop)	nuisance dust
central shops	ammonia
	total dust
pipe shop	lead (lead melter)

Appendix 2 (continued)

Industrial Hygiene Sampling Conducted by Facility

Facility Number	Chemical
Unknown	acetate xylene
	aromatics 100 n-butyl
	benzene
	coal dust-silica
	DOP
	epichlorohydrin
	exposure to dg from opening drums of bd
	grinding dust in T&I
	hexanol
	lead
	lithium
	methylene bisphenyl isocyanate
	nuisance dust
	methylene chloride
	phenol
	polychlorinated biphenyls
	refractory ceramic fibers
	respirable dust
	styrene
	total hydrocarbon
	toluene-2 4-diisocyanate and
	trichloroethane
	o-xylene
	zeolite dust

Appendix 3

INDUSTRIAL HYGIENE ASBESTOS MONITORINGS AT SRS

BUILDING

100- Reactors

100 areas
105c
105k
105l
105p
108-2k
108-l
183-2c
183k
184k
184p

200- Separations

Fbl
211f
211h
212h
221f
221h
222f
232h
234h
235f
241f
241h
284f
284h
291/292f

300- Target/Fuel Fab.

305a
313m
320m
321m

400- Heavy Water

400d
411d
420d
421d
484d

600

618g
675t
679t

700-Administration/Laboratories

701-1d
703a
704c
704m (men's restrm)
704m
704p
706f
707-1f
708a (cafe)
708-1
711a
711c
711k
714a
716a
717a
717d
717f
719a
723a
723f
735a
735a lab c101
751a
760g
772d
772f
773a
776a steam line
784a
789u

Miscellaneous

b-040
d-0179
eoc
Ford Bldg
HWCTR
lp turbine
TNX

Appendix 4

INDUSTRIAL HYGIENE SOUND LEVEL SURVEYS AT SRS, 1984-1989

BUILDING

100 -- Reactors

100c power facilities
100k power facilities
100l power facilities
100k maintenance facilities
100p power facilities
. reactor works engin. facilities

200 – Separations

200f
200f power facilities
200h
221h
232h
236h
299h

300 – Fuel/Target Fabrication

300m
300 power facilities and maintenance facilities
313m

400 – Heavy Water Production

400d power facilities

500

500 power facilities

600

683c power facilities
683d power facilities
683f power facility
683g power facilities
683h
683k power facilities
683l power facilities
683p power facilities
672t
687fh maintenance facility
687 maintenance facility

Appendix 4 (continued)

INDUSTRIAL HYGIENE SOUND LEVEL SURVEYS AT SRS, 1984-1989

BUILDING

700 - Administration/Laboratories

700a maintenance fac.
700 power facilities
706h, room 104
716a

Central Shops

central services & E & I facilities
central services works engine

Appendix 6

Diagnoses for Employee Absences Greater than Five Days in 1994. All SRS Workers

Category of Diagnoses	ICD9-CM Code	Number of Diagnoses*	Age-Adjusted Rate per 1,000**
Infections and parasitic diseases	001-139	219	14.7
Malignant neoplasms	140 -208, 230-234	29	2.8
Digestive organs	150-159	6	0.8
Respiratory system	160-165	2	0.2
Breast	174-175	5	0.2
Genitourinary	179-189	5	0.3
Nervous system	191-192	0	---
Leukemia	200-208	3	0
Benign neoplasms and other	210-229, 235-239	72	4.0
Endocrine and metabolic diseases	240-279	68	4.1
Blood and blood-forming organs	280-289	24	1.5
Mental disorders	290-319	75	3.9
Alcoholism	303	1	0.0
Drug abuse	304-305	0	0
Nervous system and sense organs	320-389	185	12.2
Circulatory system	390-459	169	13.4
Hypertension	401	25	1.8
Acute myocardial infarction	410	10	1.2
Ischemic disease, not M.I.	411-414, 429.2	44	4.4
Cerebrovascular disease	430-438	13	1.2
Respiratory system	460-519	1,224	74.8
Upper respiratory	460-465, 470-478	526	31.8
Pneumonia/ bronchitis	466, 480-487	432	26.0
Chronic respiratory conditions	490-496	207	13.0
Digestive system	520-579	342	22.7
Hernias	550-553	63	4.3
Gallbladder disease	574-575	37	2.6
Genitouninary system	580-629	333	19.7
Benign prostatic hypertrophy	600	3	0.4
Endometriosis	617	32	1.5
Ovarian cysts	620.0-620.2	33	1.6
Female genital bleeding	625-626	42	2.2
Pregnancy and childbirth (1)	630-676	268	17.4
Skin and subcutaneous tissue	680-709	39	2.2
Musculoskeletal system	710-739	471	28.8
Dorsopathies	720-724	283	15.9
Congenital anomalies	740-759	5	0.3
Certain perinatal conditions	760-779	0	0
Symptoms, signs, and ill-defined conditions	780-799	513	30.8

Appendix 6 (continued)

Diagnoses for Employee Absences Greater than Five Days in 1994. All SRS Workers

Category of Diagnoses	ICD9-CM Code	Number of Diagnoses*	Age-Adjusted Rate per 1,000**
Injury and poisoning	800-999	351	21.2
Fractures, all sites	800-829	63	4.0
Dislocations	830-839	36	2.1
Sprains and strains	840-848	108	6.6
Intracranial injuries	850-854	6	0.3
Internal injuries	860-869	0	0
Open wounds	870-897	12	0.7
Other injuries	900-999	126	7.5
Health status/health service contract	V01-V82	71	3.9
Family history of health problems	V10-V19	17	1.2
Circumstances related to reproductive development	V20-V28	31	1.5
Specific procedure/aftercare	V50-V59	14	0.8
Total minus pregnancies		**4,190**	**260.9**
TOTAL		**4,458**	**278.4**

* Includes all diagnoses reported with an absence of 5 or more days.
** Standardized to age of 1970 US population

(1) Only women aged 18-45 were included in the calculations of the rates for these diagnostic categories.

Appendix 7

Diagnoses for Employee Absences Greater than Five Days in 1994. Male Workers

Category of Diagnoses	ICD9-CM Code	Number of Diagnoses*	Age-Adjusted Rate per 1,000**
Infections and parasitic diseases	001-139	117	11.1
Malignant neoplasms	140 -208, 230-234	15	2.4
Digestive organs	150-159	4	0.8
Respiratory system	160-165	2	0.2
Breast	174-175	0	0
Genitourinary	179-189	4	0.3
Nervous system	191-192	0	---
Leukemia /lymphoma	200-208	0	---
Benign neoplasms and other	210-229, 235-239	16	1.6
Endocrine and metabolic diseases	240-279	38	3.4
Blood and blood-forming organs	280-289	2	0.2
Mental disorders	290-319	24	1.6
Alcoholism	303	1	0.1
Drug abuse	304-305	0	0
Nervous system and sense organs	320-389	77	7.1
Circulatory system	390-459	124	13.5
Hypertension	401	14	1.4
Acute myocardial infarction	410	9	1.3
Ischemic disease, not M.I.	411-414, 429.2	42	5.3
Cerebrovascular disease	430-438	11	1.3
Respiratory system	460-519	625	54.5
Upper respiratory	460-465, 470-478	262	23.5
Pneumonia/ bronchitis	466, 480-487	244	20.9
Chronic respiratory conditions	490-496	89	7.4
Digestive system	520-579	201	18.4
Hernias	550-553	52	4.7
Gall bladder disease	574-575	16	1.5
Genitourinary system	580-629	83	8.3
Benign prostatic hypertrophy	600	3	0.5
Endometriosis	617	NA	
Ovarian cysts	620.0-620.2	NA	
Female genital bleeding	625-626	NA	
Pregnancy and childbirth (1)	630-676	NA	
Skin and subcutaneous tissue	680-709	21	1.5
Musculoskeletal system	710-739	299	25.7
Dorsopathies	720-724	203	16.0
Congenital anomalies	740-759	1	0.1
Certain perinatal conditions	760-779	0	0
Symptoms, signs, and ill-defined conditions	780-799	233	19.7

Appendix 7 (continued)

Diagnoses for Employee Absences Greater than Five Days in 1994. Male Workers

Category of Diagnoses	ICD9-CM Code	Number of Diagnoses*	Age-Adjusted Rate per 1,000**
Injury and poisoning	800-999	199	16.8
Fractures, all sites	800-829	38	3.1
Dislocations	830-839	28	2.3
Sprains and strains	840-848	65	6.2
Intracranial injuries	850-854	4	0.2
Internal injuries	860-869	0	0
Open wounds	870-897	7	0.6
Other injuries	900-999	57	4.2
Health status/health service contract	V01-V82	22	1.5
Family history of health problems	V10-V19	8	0.6
Circumstances related to reproductive development	V20-V28	2	0.1
Specific procedure/aftercare	V50-V59	6	0.4
Total		**2,097**	**187.2**

* Includes all diagnoses reported with an absence of 5 or more days.

** Standardized to age of 1970 US population

(1) Only women aged 18-45 were included in the calculations of the rates for these diagnostic categories.

Appendix 8

Diagnoses for Employee Absences Greater than Five Days in 1994. Female Workers

Category of Diagnoses	ICD9-CM Code	Number of Diagnoses*	Age-Adjusted Rate per 1,000**
Infections and parasitic diseases	001-139	102	24.7
Malignant neoplasms	140 -208, 230-234	14	2.4
Digestive organs	150-159	2	0.4
Respiratory system	160-165	0	0
Breast	174-175	5	0.9
Genitourinary	179-189	1	0.1
Nervous system	191-192	0	---
Leukemia/lymphoma	200-208	3	0.5
Benign neoplasms and other	210-229, 235-239	56	10.2
Endocrine and metabolic diseases	240-279	30	5.8
Blood and blood-forming organs	280-289	22	4.0
Mental disorders	290-319	51	9.8
Alcoholism	303	0	0.0
Drug abuse	304-305	0	0
Nervous system and sense organs	320-389	108	32.7
Circulatory system	390-459	45	11.5
Hypertension	401	11	3.3
Acute myocardial infarction	410	1	0.6
Ischemic disease, not M.I.	411-414, 429.2	2	0.4
Cerebrovascular disease	430-438	2	0.8
Respiratory system	460-519	599	134.9
Upper respiratory	460-465, 470-478	264	53.7
Pneumonia/ bronchitis	466, 480-487	188	38.6
Chronic respiratory conditions	490-496	118	32.3
Digestive system	520-579	141	36.6
Hernias	550-553	11	2.4
Gall bladder disease	574-575	21	7.4
Genitourinary system	580-629	250	47.2
Benign prostatic hypertrophy	600	NA	
Endometriosis	617	32	4.5
Ovarian cysts	620.0-620.2	33	5.1
Female genital bleeding	625-626	42	10.3
Pregnancy and childbirth (1)	630-676	268	48.7
Skin and subcutaneous tissue	680-709	18	4.8
Musculoskeletal system	710-739	172	35.9
Dorsopathies	720-724	80	14.9
Congenital anomalies	740-759	4	1.1
Certain perinatal conditions	760-779	0	0
Symptoms, signs, and ill-defined conditions	780-799	280	69.6

Appendix 8 (continued)

Diagnoses for Employee Absences Greater than Five Days in 1994. Female Workers

Category of Diagnoses	ICD9-CM Code	Number of Diagnoses*	Age-Adjusted Rate per 1,000**
Injury and poisoning	800-999	152	37.1
Fractures, all sites	800-829	25	6.5
Dislocations	830-839	8	1.4
Sprains and strains	840-848	43	7.3
Intracranial injuries	850-854	2	0.7
Internal injuries	860-869	0	0
Open wounds	870-897	5	0.9
Other injuries	900-999	69	20.3
Health status/health service contract	V01-V82	49	9.6
Family history of health problems	V10-V19	9	2.7
Circumstances related to reproductive development	V20-V28	29	4.3
Specific procedure/aftercare	V50-V59	8	2.2
Total minus pregnancies		**2,093**	**478.0**
TOTAL		**2,361**	**526.7**

* Includes all diagnoses reported with an absence of 5 or more days.

** Standardzed to age of 1970 US population

(1) Only women aged 18-45 were included in the calculations of the rates for these diagnostic categories.

Appendix 10

Former SRS Workers Meeting

University of South Carolina
Aiken Campus
3:00 PM - 4:30 PM
Science Building, Room 327
June 25, 1998

Investigators Present:

Dr. David Adcock
Dr. Dan Zurosky
Dr. Yougie Huang
Pam Ferguson, Graduate Assistant
Christy Ellis, Graduate Assistant
Dr. L.P. Singh, DOE / SRS

Former Worker Present:

Mr. John H. Barnes
3941 Broxton Bridge Hwy
Ehrhardt, SC 29081

Mr. Paul L. Cook
710 Riverfront Drive
Augusta, GA 30901
706-724-1034

Mr. Richard Sutton, Jr.
3010 Roxbury Ct.
Augusta, GA 30906

Herman Boland
949 Alfred Street
Aiken, SC 29801
803-648-1502

Mr. Kyle Melton
PO Box 3052
Aiken, SC 29802

Appendix 10 (continued)

Mr. Edward A. Reel
3927 Willowood Road
Matinez, GA. 30907

Ms. Thelma J. Estes
252 E. Boundary Street
Aiken, SC 29803
803-648-4960

Charles Thorngate
1125 Parsons Lane
Aiken, SC 29803-5323
803-648-4140

Joshua W. Skeen
715 Oriole Street
Aiken, SC 29803

Simon Boozer
112 Williamsburg SE
Aiken, SC 29801

Dannie Walker
231 Post Oak Lane
N. Augusta, SC 29841

Barbara Bass
834 Magnolia Street
Aiken, SC 29801

Information Form
Former SRS Workers Meeting
Thursday, June 25, 1998

AN INVITATION TO FORMER SRS WORKERS

The U.S. Department of Energy is funding a study of former workers of the Savannah River Site (Plant) to identify individuals whose employment might have created some health risk. The study is being conducted by researchers at the University of South Carolina and the Medical University of South Carolina. The researchers would like to meet with as many former SRS employees as possible to obtain information about their work activities.

A meeting has been scheduled on the USC Aiken Campus at 3:00pm (until 5:00pm) on Thursday, June 25, 1998 in the Science Building, Room 327. If you are a former worker who was employed at SRS anytime since the beginning of site construction and would like to discuss your work experiences with the researchers, please plan to attend this meeting. Your input would add greatly to the quality of this study.

This study is an activity of the University of South Carolina and the Medical University of South Carolina

The information collected during this meeting will be used to study what medical surveillance and medical care activities, **if any**, might be needed to address any possible work related health problems in the population of former SRS workers.

Answering any of the questions on this sheet is entirely optional (voluntary). You are not required to answer these questions to be eligible for any future program or services which might be provided.

****

QUESTIONS:

1) What is your current state of health?______________________________

____

____

2) Do you believe you have any health problem which is related to your work at the SRS?

Yes No (please circle)

Appendix 10 (continued)

If yes, please describe below:

____

____

3) Do you think that you were exposed to any hazardous material during your work at the SRS?

Yes No (please circle)

If yes, what was the material and how did you become exposed?________________

____

____

4) Do you have any specific health concern or work related exposure about which you would like to see further research directed?____________________________

____

____

5) Do you have any other comments about your health and the work that you did at the Savannah River Site?____

____

____

Remember, providing this information is entirely optional.

Name:____

Date of Birth:____

Address:____

Telephone #____

Appendix 10 (continued)

Date employed at SRS:____

Date employment ended:______________________________________

Job Title:____

srsquestionnaire
6/24/98

Summary of Responses to Survey at Public Meeting of Former SRS Workers, June 25, 1998

#1 Current state of health?
Good
Chronic neck pain unknown cause: 1
Blank: 1

#2 Do you believe you have any health problem related to work at SRS?
No: 5
Maybe: 1 (hypothyroid, chronic neck pain, and vertigo)

#3 Do you think you were exposed to any hazardous material during your work at SRS?
Yes: 6 (tritium-uranium, H_2S, radiation-reactor charge/discharge, chemical spill, plutoium-tritium, external radiation (28,965 rem), hazard material)
No: 1
Blank: 2

#4 Do you have any specific health concern about which you would kike to see further researched?
No: 2
Blank: 2
Maybe: 1
Yes: 3 (low dose tritium exposure, skin-lung cancers, governmental citation in 1977)

#5 Do you have any other comments about your health and the work that you did at SRS?
Want to see annual physicals: 1
Did not care for Graveyard shift
No: 5

Appendix 11

Selected Documents Showing Accidental Releases of Contaminants at SRS

(as compiled by investigators from the Medical Surveillance for SRS Construction Workers project – see Center to Protect Workers' Rights, 1998)

"Contamination of the Hot Gang Valve Corridor and First Level Clean Areas of Bldg. 221-F, September 13, 1960", DSPU 60-11-34.

"Explosion and Fire in the Uranium Trioxide Production Facilities at he Savannah river Plant on February 12, 1975", DPSPU 76-11-1.

Special Incident Report "Environmental Release of Iodine-131 May 29-June 23, 1961", DPSUPU 61-11-21.